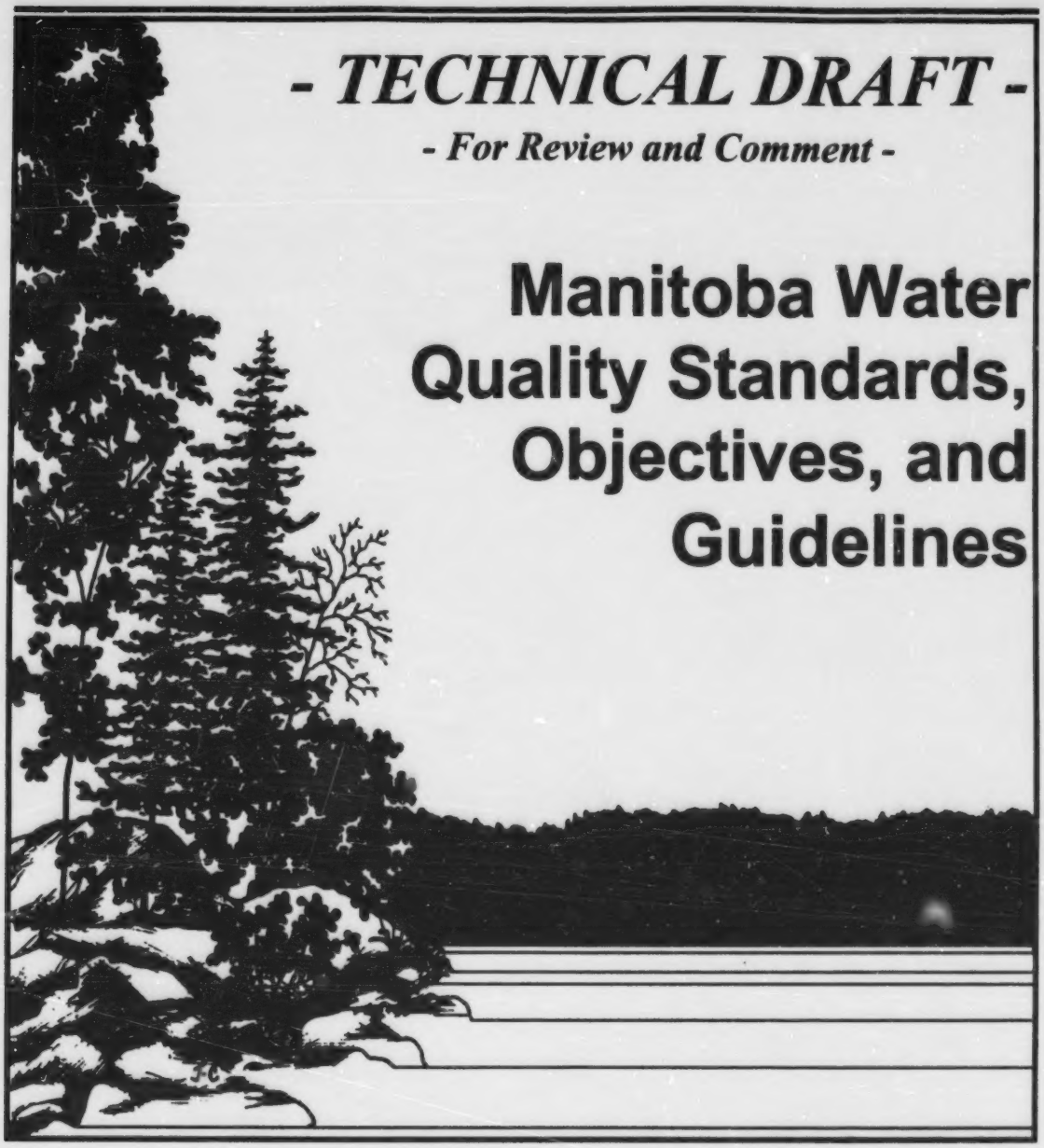

- TECHNICAL DRAFT -

- For Review and Comment -

Manitoba Water Quality Standards, Objectives, and Guidelines

Technical Draft: February 1, 2001

Manitoba Conservation Report 2001-01

Manitoba Conservation

101-03305/

Technical Draft: February 1, 2001
For Review and Comment

Manitoba Conservation Report 2001-01

MANITOBA WATER QUALITY STANDARDS, OBJECTIVES, AND GUIDELINES

D.A. Williamson, Manager
Water Quality Management Section
Manitoba Conservation

Manitoba Conservation

Printed on Recycled Paper

OPPORTUNITY FOR REVIEW AND REQUEST FOR COMMENTS

Revisions are being proposed to Manitoba Conservation's water quality objectives. A process is outlined to ensure an open and extensive opportunity for widespread public review.

There is a need for periodic revisions.

On-going, periodic revisions are necessary to ensure that new scientific findings are routinely incorporated and that emerging approaches to enhanced environmental protection are considered. The existing Manitoba Surface Water Quality Objectives were last revised in 1988.

- Since 1988, Manitoba Conservation has gained considerable experience in applying the Manitoba Surface Water Quality Objectives. As a result of this experience, it has become apparent that some sections could benefit from clarification and that additional information should be provided. For example, there was a need to have the objectives also apply to the protection of ground water rather than only surface water, new sections should be included to protect overall biological integrity, and objectives should be included to protect other aquatic media such as sediments and fish tissue rather than only the water component.
- Since 1988, much new scientific information has emerged that warrants consideration. For example, the US Environmental Protection Agency published new criteria in late 1999 for ammonia that supercedes the previous information used to derive Manitoba's 1988 objective. Ammonia is a common pollutant in a number of discharges to waters in southern Manitoba. Similar scientific information has also been recently published for trace metals, suspended sediments, and several other materials.
- Since 1988, new approaches to environmental protection have been developed by the Canadian Council of Ministers of the Environment (CCME). Manitoba is an active member of the CCME. There was a need, therefore, to fully integrate these new approaches into the Manitoba Surface Water Quality Objectives.

A three-phase review period has been developed to allow extensive opportunity for review and comment. Release of this Technical Draft begins the second phase.

Manitoba Conservation is interested in hearing from you about these proposed revisions. An extended review period is planned that will be divided into the following three phases:

PHASE I - INFORMATION PERIOD AND OPPORTUNITY TO PROVIDE INITIAL COMMENTS

April 20, 2000 - September 29, 2000

- This portion of the review phase has now ended.
- The Manitoba Water Quality Standards, Objectives, and Guidelines were available for public review. This phase was intended to provide a full opportunity for all those with an interest in this program to gain an understanding of the

suggested changes and to provide initial comments. Copies were placed in Manitoba Conservation's public registries and an electronic copy was posted on Manitoba Conservation's internet website (http://www.gov.mb.ca/environ). Information on various aspects of the proposed revisions was provided to agencies or individuals as requested. Initial comments were to be submitted in writing by September 29, 2000.

September 29, 2000 - February 1, 2001

- The Manitoba Water Quality Standards, Objectives, and Guidelines were revised to reflect comments received during the initial review period. Comments were summarized along with a response from Manitoba Conservation. Comments and associated responses were distributed to all reviewers, were placed in Manitoba Conservation's public registries, and an electronic copy was posted on Manitoba Conservation's internet website.

PHASE II - DETAILED TECHNICAL REVIEW PERIOD

February 1, 2001 - October 31, 2001

- The revised Manitoba Water Quality Standards, Objectives, and Guidelines will be available for a more detailed review. Copies of the revised document and the Summary of Comments arising from this review phase will again be placed in Manitoba Conservation's public registries and will be posted on the department's internet website. Comments should be submitted in writing by October 31, 2001.
- Manitoba Conservation would be pleased to provide further information to individuals, associations, or other groups. In addition, if there is sufficient interest, the Water Quality Management Section will host information sessions at various stages throughout the review process

November 1, 2001 - December 31, 2001

- Revisions will be incorporated. Copies of both the revised document and the Summary of Comments will again be placed in Manitoba Conservation's public registries and will be posted on the department's internet website.

PHASE III - ADDITIONAL REVIEW PERIOD

January 1, 2002 - March 31, 2002

- This third phase will also allow for a further opportunity to provide comments, and in particular, to comment on the proposed revisions made as a result of comments received during the initial and detailed review phases. The third phase will also allow for further discussion and consensus-building on those issues that may remain unresolved followed the initial and detailed review phases. This third phase will begin around the start of the new calendar year, 2002 and will last until at least

the end of the fiscal year and longer, if necessary. Consensus will attempt to be achieved on those issues that may remain unresolved.

Future

- The Manitoba Water Quality Standards, Objectives, and Guidelines will be updated periodically in the future to reflect the emergence of new scientific information and administrative experience.

Please forward comments to the following:

Dwight Williamson, Manager
Water Quality Management Section
Manitoba Conservation
123 Main Street, Suite 160
Winnipeg MB R3C 1A5
Telephone: (204) 945-7030
Toll Free: 1-800-282-8069 (7030)
Facsimile: (204) 948-2357
E-mail: dwilliamso@gov.mb.ca

Please feel free to contact Dwight Williamson should you require further information.

FOREWORD

Manitoba Conservation ensures a high level of environmental quality by identifying, evaluating, and managing existing and potential future risks to the environment and human health. A variety of scientific tools and management strategies are used in a proactive manner to protect, maintain, and rehabilitate water quality to meet this mission. Similar to many other jurisdictions, two general water quality management strategies are simultaneously used. First, all activities and waste discharges are controlled to the extent that is reasonably practical and economically achievable using a consistent technology-based approach for each development sector. This is consistent with pollution prevention principles that have been historically applied in Manitoba on a routine basis and, more recently, described in the Canadian Council of Ministers of the Environment's (CCME) Canada-Wide Accord on Environmental Harmonization. Second, when more stringent environmental controls are required to protect important water uses, a water quality-based approach is then used. Additional environmental limits are derived using the water quality-based approach to ensure that applicable ambient water quality standards, objectives, or guidelines are not exceeded.

This document, once finalized, will supercede the "Manitoba Surface Water Quality Objectives" (Williamson 1988a) and "The Development and Use of Water Quality Objectives in Manitoba" (Williamson 1990).

New Advancements Proposed in this Document

Water quality standards, objectives, and guidelines are proposed to now apply to a wide range of water-related media in Manitoba, including both ground and surface waters, lake and river bottom sediments, and fish tissues. A three-tiered approach is proposed to consolidate and harmonize Manitoba's use of standards, objectives, and guidelines with those developed through other national efforts (Figure 1):

- ***Tier I - Water Quality Standards:***
  - Propose guidance on minimum levels of treatment that must be achieved by all dischargers in Manitoba, regardless of location, in order to satisfy the technology-based approach and to be consistent with the pollution prevention principle.
  - It is proposed that *Tier I - Water Quality Standards* also include Canada-Wide Standards presently being developed by the CCME under the National Accord on Environmental Harmonization. The Canada-Wide Standards contained in Tier I would be implemented in accordance with the strategies negotiated for each standard through the CCME process. Where appropriate, Canada-Wide Standards are being developed using a risk-based approach. *Tier I - Water Quality Standards*, once fully developed by the CCME, will reflect a unique Canadian approach to maintaining a consistent high level of environmental quality across the nation. Incorporation of these Canada-Wide Standards into this document would ensure their intended application to control or manage impacts to the aquatic environment.
  - Although called "standards", *Tier I - Water Quality Standards* would not be legally-binding unless they have been incorporated elsewhere into legislation. This term implies, as intended, that significant site-specific or regional-specific modification of *Tier I - Water Quality Standards* would not be allowed except where specifically indicated.

- ***Tier II - Water Quality Objectives:***

  - It is proposed that *Tier II - Water Quality Objectives* be limited to a short list of materials that are common pollutants in Manitoba. Similar to the existing "Manitoba Surface Water Quality Objectives", most proposed *Tier II - Water Quality Objectives* are based on the principles advanced by the United States Environmental Protection Agency (US EPA) that healthy aquatic ecosystems can tolerate some stress and can recover. Based upon these principles, they would provide protection from unacceptable impacts to all but a small percentage of genera (5%). Exceptions are provided for important ecological, recreational, and commercial species, endangered or rare species, and High Quality and Exceptional Value waters that may require additional protection. Therefore, there is good confidence that *Tier II - Water Quality Objectives* would provide a reasonable, cost-effective level of protection without being over-protective or unacceptably under-protective. It is intended that *Tier II - Water Quality Objectives* be used directly to assist in developing discharge limitations.

  - In addition to new, updated water quality objectives that reflect current scientific knowledge for pollutants commonly managed by Manitoba Conservation, new approaches are being proposed for their implementation. New low-flow design policies are proposed to guide the control of discharges that occur to Manitoba's rivers and streams. For example, it is proposed that common reliance be reduced upon the annual 7Q10 (the minimum, average low flow that occurs with a recurrence frequency of once each 10 years). For the protection of aquatic life, it is proposed that these be replaced by various minimum flow calculations that consider averaging periods and exceedance frequency that are biologically-relevant. In the past, Manitoba Conservation has allowed 7Q10s to be calculated on a seasonal or monthly basis. While it is proposed that this method continue to be allowed, the appropriateness of this calculation is presently being reviewed to ensure that it provides the intended level of protection.

  - New objectives are proposed for a number of common trace elements such as arsenic, cadmium, copper, lead, nickel, and zinc that need to be controlled in Manitoba. It is proposed that these be expressed as dissolved forms rather than the previous total recoverable forms to better reflect the fraction that is most toxic to aquatic life.

  - New objectives are proposed for ammonia to reflect new scientific findings of the US EPA. Objectives for dissolved oxygen are now proposed as concentrations rather than as per cent saturation, following guidance provided by the US EPA, British Columbia, and the CCME. In addition, objectives for suspended sediment are now proposed both as maximum acceptable concentrations and as allowable exceedances based upon a per cent change from natural background concentrations.

  - Mixing zone guidelines would remain largely unchanged, but additional clauses are proposed to provide superior guidance to prevent acute lethality within the initial zone of dilution. These clauses would require whole effluents not to be acutely lethal to aquatic life, as demonstrated by 96 hr LC_{50} tests, unless it can be shown through mixing zone modelling that complete mixing of effluent with receiving water occurs quickly.

  - As intended by the use of the term "objectives", there is greater opportunity for modification of *Tier II - Water Quality Objectives* to account for unique, site-specific or regional-specific considerations relative to *Tier I - Water Quality Standards*.

- ***Tier III - Water Quality Guidelines:***

  - It is proposed that *Tier III - Water Quality Guidelines* contain guidelines developed by the CCME for numerous materials. Manitoba Conservation actively participates in the CCME process to assist in the development of various environmental management concepts and leadership principles as well as practical tools to assist in the management of man-made stressors to the environment. One of these tools, the CCME environmental quality guidelines, are becoming recognized world-wide for their value in managing pollutants in the environment. *Tier III - Water Quality Guidelines* are derived by the CCME to ensure that the most sensitive species likely to occur in Canadian waters are protected at all times along with an adequate margin of safety. Consequently, *Tier III - Water Quality Guidelines* generally would be more conservative than *Tier II - Water Quality Objectives*. As intended by the CCME, *Tier III - Water Quality Guidelines* would principally be used in Manitoba to assist in interpreting ambient water quality monitoring data to identify emerging or potential water quality problems. Where required, *Tier III - Water Quality Guidelines* could be elevated to *Tier II - Water Quality Objectives* to assist in developing control strategies for new materials.

  - The general narrative objectives previously identified in the Manitoba Surface Water Quality Objectives (Williamson 1988a) have been retained, but are now proposed to be part of the *Tier III - Water Quality Guidelines*.

  - Manitoba Conservation, similar to a number of other jurisdictions, is developing a strategy to better manage plant nutrients in our aquatic ecosystems. It is anticipated that this strategy will lead to the development of more appropriate site-specific or regional-specific water quality objectives or guidelines for nutrients. Once developed, these would be incorporated into future editions of this document. In the meantime, it is proposed that the narrative guidelines still be retained for nutrients such as nitrogen and phosphorus until this more appropriate Nutrient Management Strategy is developed for Manitoba. It is generally recognized, however, that the narrative guidelines for phosphorus likely do not apply to many streams in the Canadian prairie region since other factors such as turbidity, stream velocity, nitrogen, and other conditions most often limit algal growth. As well, relatively high levels of phosphorus in excess of the narrative guidelines may arise naturally from the rich prairie soils.

  - Sediment and tissue residue guidelines are proposed for many persistent materials that may accumulate in lake or river bottom sediments and fish tissue.

  - Narrative biological guidelines are proposed to ensure the protection of ecosystem structure and function. These would augment the comprehensive chemical-specific guidelines.

  - Narrative guidelines are proposed to guide the intentional introduction of non-native aquatic species to Manitoba waters and to prevent the accidental introduction of other, potentially harmful, non-native aquatic species.

  - Narrative guidelines are proposed to guide the development of water conservation measures and to ensure that sufficient minimum in-stream flows are maintained to protect aquatic life communities.

  - It is intended that *Tier III - Water Quality Guidelines* would be more flexible than either *Tier I - Water Quality Standards* or *Tier II - Water Quality Objectives*. This meaning is implied by the use of the term "guidelines". Some *Tier III - Water Quality Guidelines* may lend themselves for use in adaptive management, whereas *Tier I - Water Quality Standards* and *Tier II - Water Quality Objectives* are intended to be more prescriptive.

Future Revisions

The Manitoba Water Quality Standards, Objectives, and Guidelines will be revised on a continual basis in the future as new scientific information emerges and as further experience is gained in the administrative application of these principles, policies, and guidance. A number of activities are presently underway both in Manitoba and elsewhere in Canada that may result in significant new information arising within the near future. For example, studies by the City of Winnipeg are underway to develop a site-specific or regional-specific objective for ammonia for the Red and Assiniboine rivers within and downstream of Winnipeg. The City of Brandon, City of Portage la Prairie, Manitoba Conservation, and others are undertaking work on the Assiniboine River that may assist in developing appropriate nutrient objectives or guidelines. Manitoba Conservation, along with other agencies in the Canadian prairies, is developing an overall strategy to better manage plant nutrients in prairie streams. As well, new principles relating to environmental protection in Canada continue to be developed through national processes, such as the CCME. As results emerge and are evaluated, modifications will be made to the Manitoba Water Quality Standards, Objectives, and Guidelines wherever appropriate.

For Further Information

For further information on the Manitoba Water Quality Standards, Objectives, and Guidelines or to obtain copies of this document, please contact:

Dwight Williamson, Manager
Water Quality Management Section
Manitoba Conservation
123 Main Street, Suite 160
Winnipeg MB R3C 1A5

Telephone: (204) 945-7030
Toll Free: 1-800-282-8069 (7030)
Facsimile: (204) 948-2357
E-mail: dwilliamso@gov.mb.ca

This document has also been placed on Manitoba Conservation's Internet Web Page and can be viewed or downloaded. The Web Site address is http://www.gov.mb.ca/environ. The Internet will be the principle medium for distribution of the Manitoba Water Quality Standards, Objectives, and Guidelines.

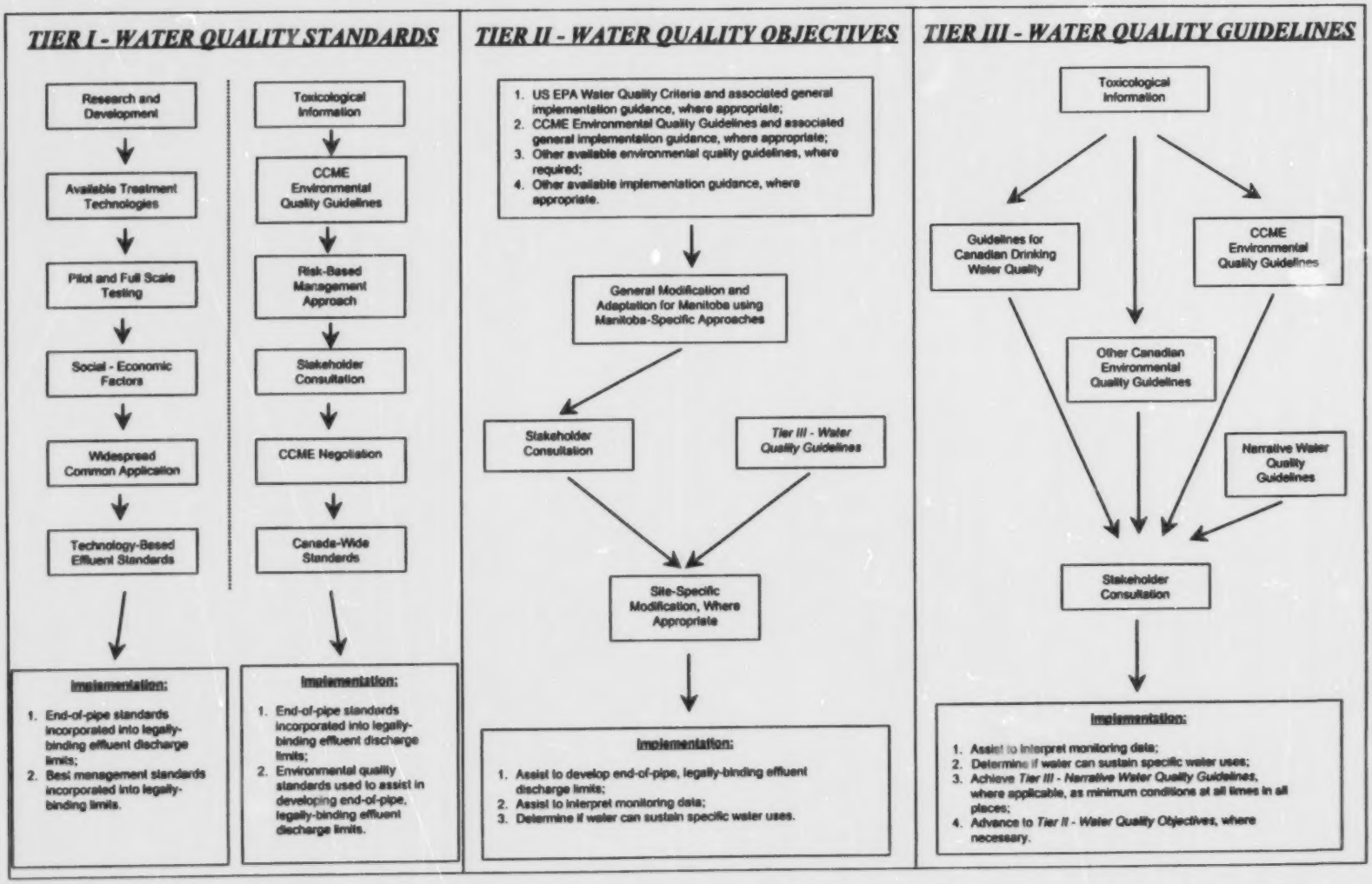
TIER I - WATER QUALITY STANDARDS
Research and Development
Available Treatment Technologies
Pilot and Full Scale Testing
Social - Economic Factors
Widespread Common Application
Technology-Based Effluent Standards
Implementation:
1. End-of-pipe standards incorporated into legally-binding effluent discharge limits;
2. Best management standards incorporated into legally-binding limits.
Toxicological Information
CCME Environmental Quality Guidelines
Risk-Based Management Approach
Stakeholder Consultation
CCME Negotiation
Canada-Wide Standards
Implementation:
1. End-of-pipe standards incorporated into legally-binding effluent discharge limits;
2. Environmental quality standards used to assist in developing end-of-pipe, legally-binding effluent discharge limits.
TIER II - WATER QUALITY OBJECTIVES
1. US EPA Water Quality Criteria and associated general implementation guidance, where appropriate;
2. CCME Environmental Quality Guidelines and associated general implementation guidance, where appropriate;
3. Other available environmental quality guidelines, where required;
4. Other available implementation guidance, where appropriate.
General Modification and Adaptation for Manitoba using Manitoba-Specific Approaches
Stakeholder Consultation
Tier III - Water Quality Guidelines
Site-Specific Modification, Where Appropriate
Implementation:
1. Assist to develop end-of-pipe, legally-binding effluent discharge limits;
2. Assist to interpret monitoring data;
3. Determine if water can sustain specific water uses.
TIER III - WATER QUALITY GUIDELINES
Toxicological Information
Guidelines for Canadian Drinking Water Quality
CCME Environmental Quality Guidelines
Other Canadian Environmental Quality Guidelines
Narrative Water Quality Guidelines
Stakeholder Consultation
Implementation:
1. Assist to interpret monitoring data;
2. Determine if water can sustain specific water uses;
3. Achieve Tier III - Narrative Water Quality Guidelines, where applicable, as minimum conditions at all times in all places;
4. Advance to Tier II - Water Quality Objectives, where necessary.

Figure 1. General derivation and intended application of *Tier I - Water Quality Standards*, *Tier II - Water Quality Objectives*, and *Tier III - Water Quality Guidelines*.

TABLE OF CONTENTS

OPPORTUNITY FOR REVIEW AND REQUEST FOR COMMENTS i
FOREWORD iv
New Advancements Proposed in this Document iv
Future Revisions vii
For Further Information vii
TABLE OF CONTENTS ix
LIST OF TABLES x
LIST OF FIGURES x
TIER I - WATER QUALITY STANDARDS 1
Implementation Policies 2
General Application 2
Tier I - Water Quality Standards 2
Dioxins and Furans 2
Mercury 2
Total Petroleum Hydrocarbons 2
Municipal Wastewater Effluents 2
Other Effluents or Activities Governed by Provincial or Federal Regulation 3
TIER II - WATER QUALITY OBJECTIVES 5
Implementation Policies 6
General Application 6
Exceedance of Objectives due to Natural Conditions 6
Levels of Protection 6
Routine Protection of Water Uses 6
High Quality Waters 7
Exceptional Value Waters 8
Minimum Design Flows and Levels 8
Rivers and Streams 8
Intermittent Streams 9
Lakes, Bays, Marshes, Sloughs, Impoundments, and Other Wetlands 10
Ground Water 10
Mixing Zones 10
Tier II - Water Quality Objectives 12
TIER III - WATER QUALITY GUIDELINES 36
Implementation Policies 37
General Application 37
Advancement to Tier II - Water Quality Objectives 37
Protection of Surface Water Drinking Sources 38
Tier III - Narrative Water Quality Guidelines 38
Tier III - Numerical Water Quality Guidelines 41
RATIONALE FOR PROPOSED REVISIONS, DEFINITIONS, PROGRAM HISTORY, AND REFERENCES 58
Rationale for Proposed Revisions 59
Definitions 69
Program History 73
References 75

LIST OF TABLES

Table 1. Matrix showing *Tier II - Water Quality Objectives* for ammonia at pH increments of 0.1 units between 6.50 and 9.00 and at temperature increments of 5°C between 0°C and 30°C. 26

Table 2. Matrix showing *Tier II - Water Quality Objectives* for various metals at hardness increments of 5 mg/L between 5 and 400 mg/L. 33

LIST OF FIGURES

Figure 1. General derivation and intended application of *Tier I - Water Quality Standards*, *Tier II - Water Quality Objectives*, and *Tier III - Water Quality Guidelines*. viii

TIER I - WATER QUALITY STANDARDS

February 1, 2001: Technical Draft for Review and Comment

IMPLEMENTATION POLICIES

General Application

Tier I - Water Quality Standards contain two general types of guidance. First, minimum standards are identified for common classes of discharges in Manitoba. These standards form the basis of the technology-based approach to the prevention of pollution, consistent with the general historical practice in Manitoba, and ensure that best available, economically achievable treatment technologies for each sector are utilized to treat all wastes that are amenable to treatment, regardless of location. In a number of cases, these technology-based standards are already contained in existing provincial and federal regulations and are merely referenced here for completeness. There is little or no opportunity to modify the technology-based standards at any site except where specifically indicated.

Second, *Tier I - Water Quality Standards* contain Canada-Wide Standards developed and negotiated by the CCME under the Canada-Wide Accord on Environmental Harmonization. Included with each Canada-Wide Standard is an implementation protocol. Information on the Canada-Wide Accord on Environmental Harmonization and Canada-Wide Standards is available from the CCME's website at http://www.ccme.ca.

TIER I - WATER QUALITY STANDARDS

Variable	Standard	Implementation
Dioxins and Furans	Under Development	Under Development
Mercury	Under Development	Under Development
Total Petroleum Hydrocarbons	Under Development	Under Development
Municipal Wastewater Effluents	Secondary Treatment Technologies	Effluent quality must achieve the following minimum standards: • 200 fecal coliform organisms / 100 mL (may be applied on a seasonal basis) • 30 mg/L Biochemical Oxygen Demand • 30 mg/L Total Suspended Sediments (excluding growing algae)

Variable	Standard	Implementation
Other Effluents or Activities Governed by Provincial or Federal Regulation:		
• Metal Mining Liquid Effluents	• Best Practical Technology, to prevent contamination of surface and ground water, as defined by the Metal Mining Liquid Effluent Regulations of the federal Fisheries Act	As defined by the Metal Mining Liquid Effluent Regulations of the federal Fisheries Act including monthly arithmetic mean concentrations not to exceed: • 0.5 mg/L Total Arsenic • 0.3 mg/L Total Copper • 0.2 mg/L Total Lead • 0.5 mg/L Total Nickel • 0.5 mg/L Total Zinc • 25.0 mg/L Total Suspended Matter • 10.0 pBq/L Dissolved Radium
• Pulp and Paper Mill Effluents	• Best Practical Technology, to prevent contamination of surface and ground water, as defined by the Pulp and Paper Effluent Regulations of the federal Fisheries Act	As defined by the Pulp and Paper Effluent Regulations of the federal Fisheries Act including: • limits on the discharge of Biochemical Oxygen Demand based upon reference production rates • limits on the discharge of Total Suspended Solids based upon reference production rates • discharges not to be acutely lethal
• Storage and Handling of Gasoline	• Best Practical Technology, to prevent contamination of surface and ground water, as defined by the Storage and Handling of Gasoline and Associated Products Regulation (Manitoba Regulation 97/88 R) under The Manitoba Environment Act (C.C.S.M. c. E125)	• As defined by the Storage and Handling of Gasoline and Associated Products Regulation (Manitoba Regulation 97/88 R) under The Manitoba Environment Act (C.C.S.M. c. E125)

Variable	Standard	Implementation
• Livestock Manure	• Best Practical Technology, to prevent contamination of surface and ground water, as defined by the Livestock Manure and Mortalities Management Regulation (Manitoba Regulation 42/98) under The Manitoba Environment Act (C.C.S.M. c. E125)	As defined by the Livestock Manure and Mortalities Management Regulation (Manitoba Regulation 42/98) under The Manitoba Environment Act (C.C.S.M. c. E125) including: • application of manure at agronomic rates to prevent contamination of ground water • application of manure in such a manner to avoid loss beyond the boundaries of the agricultural property
• Protection of Ground Water Quality	• Best Practical Technology, to prevent contamination of ground water, as defined by The Ground Water and Water Well Act (C.C.S.M. c. G110) and the Well Drilling Regulation (Manitoba Regulation 28/88 R)	As defined by The Ground Water and Water Well Act (C.C.S.M. c. G110) and the Well Drilling Regulation (Manitoba Regulation 28/88 R) including: • the temperature of water entering a recharge well should not be more than 5°C different than the ground water at the time of initial installation • for water used in cooling systems, no chemicals should be added to water being recharged
• Private Sewage Systems	• Best Practical Technology, to prevent contamination of surface and ground water, as defined by the Private Sewage Disposal Systems and Privies Regulation (Manitoba Regulation 95/88 R)	• As defined by the Private Sewage Disposal Systems and Privies Regulation (Manitoba Regulation 95/88 R)
• Other Discharges or Activities	• As defined by applicable provincial or federal regulation to prevent contamination of surface and ground water.	• As defined by applicable provincial or federal regulation

TIER II - WATER QUALITY OBJECTIVES

February 1, 2001: Technical Draft for Review and Comment

IMPLEMENTATION POLICIES

General Application

Tier II - Water Quality Objectives are defined for a limited number of common pollutants in Manitoba that are routinely controlled through licencing under The Manitoba Environment Act. These objectives form the basis for the water quality-based approach when additional restrictions need to be developed to protect important uses of ground or surface waters beyond those defined under *Tier I - Water Quality Standards* or other controls to which dischargers are subject.

These objectives provide the fundamental link between environmental management regulatory activities, ambient water quality monitoring data, scientific toxicological information, water uses, and public expectations concerning environmental quality.

These objectives, in conjunction with other information such as downstream waters uses, existing water quality characteristics, and stream discharge volumes, can also be used by developers and project planners to determine the wastewater treatment requirements likely associated with any specific location. To be most effective, this information should be used early in project planning to accurately estimate the environmental control costs associated with any proposed location.

At some sites, further modification of *Tier II - Water Quality Objectives* may be required to better account for site-specific or regional-specific factors such as the greater or lesser sensitivity of resident species, unique influence of the receiving water on toxicity, or other factors. Scientific protocols have been developed by a number of agencies (*e.g.*, US EPA 1994a, MacDonald 1997, CCME 1999) to guide the modification of water quality objectives at specific sites. These or other scientifically rigorous methods should be followed when site-specific or regional-specific modifications are made.

Exceedance of Objectives due to Natural Conditions

Waters may have natural characteristics which exceed a number of water quality objectives. These naturally occurring situations are normal where, for example, productivity of aquatic life communities may be constrained or limited by natural conditions. In these cases, water quality objectives may be unattainable. Naturally occurring conditions that exceed the objectives should not be considered as violations and additional impairment by man-made activities should not occur unless it can be demonstrated that important water uses will not be further impaired.

Levels of Protection

Waterbodies in Manitoba can be protected to one of three different and successively higher levels of quality:

- Routine Protection of Water Uses

Water quality will be managed in most ground and surface waters in Manitoba through application of the Routine Protection of Water Uses. This routine level of protection is achieved by simultaneously using a consistent, technology-based approach, as defined by *Tier I - Water Quality Standards*,

and when required, deriving additional, more stringent requirements using the water quality-based approach, as defined by *Tier II - Water Quality Objectives*.

The routine level of protection of water uses will ensure that all pollutants are reduced or eliminated with the use of standard treatment technologies commonly available to each unique sector. This approach also recognizes that in some cases, the sole use of common, technology-based treatment systems may not provide adequate protection to a specific body of water (*e.g.*, in situations involving a large volume of effluent discharge to a small stream, a large number of industries discharging to a single body of water, or other similar situations). In these cases, water quality objectives are used to develop effluent limitations that will provide the required protection.

This level will provide reasonable protection from unacceptable impacts to all but a small percentage of aquatic species for most of the time and, therefore, reflects the principle advanced by the US EPA that healthy communities can tolerate some stress and can recover. Similarly, other water uses are provided reasonable protection from most, but not all impacts.

- High Quality Waters

Some surface or ground waters in Manitoba that have (1) biological, chemical and physical quality better than the standards, objectives, and guidelines and (2) support a high quality water use may be designated as "High Quality". Waters suitable for inclusion may include:

(a) Waters that flow through or that are bounded by Provincial or National Parks;

(b) Waters within relatively undisturbed aquifers or watersheds;

(c) Waters possessing outstanding quality characteristics;

(d) Waters that support a diverse or unique flora and fauna which are sensitive to man-induced water quality alterations;

(e) Waters designated as Canadian Heritage Rivers.

Measurable or calculable degradation that will jeopardize the designated high quality use should not occur as a result of human activity unless:

(a) The proposed new, additional or increased discharge or discharges of pollutants is justified;

(b) Such proposed discharges will not preclude any use presently possible in such waters and downstream from such waters, and will not result in exceedances of the water quality standards, objectives, and guidelines. Should the High Quality use involve the protection of aquatic life and wildlife, all life stages of all resident organisms likely to be affected will be protected at all times. Consequently, the specific numerical standards, objectives, and guidelines may be adjusted to reflect this additional degree of protection; and

(c) Such proposed projects or developments which will result in new,

additional or increased discharges of pollutants into such waters should be required to utilize the best available combination of treatment, land disposal, re-use and discharge technologies to control such wastes, including the use of best management practices to curb soil erosion.

This level will provide protection to all species in all places at all times. When development is justified, risk of unanticipated impacts will be minimized by requiring the use of best available treatment technologies.

At the present time, the Upper Burntwood, Upper Grass River, and Clearwater Lake watersheds have been designated as High Quality Waters.

- **Exceptional Value Waters**

Some surface waters that have (1) biological, chemical, and physical quality better than the established standards, objectives, and guidelines and (2) support a combination of aquatic life and wildlife and recreational uses of exceptional recreational and ecological value will be given an "Exceptional Value" designation. Waters suitable for inclusion are as follows:

(a) Ecological Reserves;

(b) Wild and scenic rivers or lakes;

(c) Waters or watersheds providing habitat for rare or endangered flora and fauna;

(d) Waters considered sensitive such that irreversible harm will result following human impact;

(e) Waters whose exceptional quality and value as a future resource precludes the assignment of present uses;

(f) Waters designated as Canadian Heritage Rivers.

Water courses designated as Exceptional Value should not receive any alterations that result in measurable, calculable, or perceived water quality degradation or degradation of other values deemed exceptional.

This level will provide a near zero risk of unanticipated impacts since water bodies designated as Exceptional Value will be virtually removed from the opportunity for development.

No water bodies have yet been designated as Exceptional Value.

Minimum Design Flows and Levels

Ideally, *Tier II - Water Quality Objectives* should apply at all times. However, this is generally viewed as being unreasonable since it would require the construction of costly treatment facilities capable of meeting *Tier II - Water Quality Objectives* even during periods of infrequent and extreme low stream flows. Thus, specific low flow levels have been chosen below which *Tier II - Water Quality Objectives* do not apply:

- **Rivers and Streams**

Specific guidance is provided with each *Tier II - Water Quality Objective*. In general, however, most aquatic life communities will be reasonably protected

from unacceptable effects if *Tier II - Water Quality Objectives* are not exceeded more than once in each three year period. The US EPA (1994) reported that exceedance frequencies greater than once each three years would result in aquatic communities constantly being in a state of recovery. They also advised that this exceedance frequency may be too great for some sensitive communities, while others may be able to recover more quickly, particularly those with numerous refugia. For those *Tier II - Water Quality Objectives* intended to prevent unacceptable chronic effects, the minimum design flow that corresponds to this return frequency is either the 4-Day, 3-Year Biological Flow or the 7Q10 Hydrological Flow, and in the case of ammonia, an additional 30-Day, 3-Year Biological Flow or 30Q10 Hydrological Flow is specified. For those *Tier II - Water Quality Objectives* intended to prevent acute effects, the minimum design flow that corresponds to this return frequency is either the 1-Day, 3-Year Biological Flow or the 1Q10 Hydrological Flow. Comparative analyses has shown that the 4-Day, 3-Year Biological Flow is approximately 10% less than the 7Q10 Hydrological Flow. In cases where minimum design flows are desired to be expressed on a seasonal or monthly basis, 7Q10s may be calculated using applicable flow data for the desired seasons or months.

For water uses other than aquatic life, reasonable protection should be provided if *Tier II - Water Quality Objectives* apply for all flows 7Q10.

In cases where the minimum design flow calculated by either the biological or hydrological method is 0.003 m^3/s or less, the guidance for Intermittent Streams, provided in the following section, should apply.

Actual, reconstructed, or predicted future hydrological data used to derive minimum design flows should be verified by professional hydrologists within Manitoba Conservation, and should consider present or likely future stream management policies.

Tier II - Water Quality Objectives should apply at all times if important uses are supported because of pooling of water during periods of low natural flows.

The applicable narrative *Tier III - Water Quality Guidelines* should apply at all times regardless of the amount of flow.

- Intermittent Streams

Intermittent streams and natural or man-made drainage channels receive water from precipitation from small watersheds (usually less than 1 km^2 in area) and from ground water sources and, therefore, usually flow during short periods. Such streams however, are an integral part of the surface water resources of Manitoba. *Tier II - Water Quality Objectives* should apply to all such streams when the flow is 0.003 m^3/s or greater. When discharge within intermittent streams is less than this flow, minimum levels of quality should be maintained in order to not exceed *Tier II - Water Quality Objectives* within downstream water bodies to which the intermittent stream is tributary.

Similar to other larger streams, *Tier II - Water Quality Objectives* should

apply at all times if important uses are supported because of pooling during periods of low natural flows.

The applicable narrative *Tier III - Water Quality Guidelines* should apply at all times regardless of the amount of flow.

- Lakes, Bays, Marshes, Sloughs, Impoundments, and Other Wetlands

Tier II - Water Quality Objectives apply at all times to lakes, bays, marshes, sloughs, impoundments, and other wetlands unless they are a defined part of an effluent system prior to the final discharge point.

- Ground Water

Tier II - Water Quality Objectives apply at all times to ground water.

Mixing Zones

Mixing zones should be determined on a case-by-case basis utilizing a thorough knowledge of local conditions. Normally, geometric size constraints will not be assigned due to the complex nature of the mixing properties of liquids. The following guidelines should apply to mixing zones, where applicable, in order to minimize the loss of value such that water uses are not unacceptably impaired (US EPA 1994a, US EPA 1994b, with modifications):

(a) The mixing zone should be as small as practicable and should not be of such size or shape as to cause or contribute to the impairment of water uses outside the zone;

(b) The mixing zone should be designed to allow an adequate zone of passage for the movement or drift of all stages of aquatic life:

(i) For those materials that elicit an avoidance response from aquatic life, the mixing zone should contain not more than 25% of the cross-sectional area or volume of flow at any transect in the receiving water. Should a proportion of the stream width greater than 25% be selected for these materials, the mixing zone could act similar to a physical barrier and could effectively preclude the passage of aquatic life;

(ii) The mixing zone should not be acutely lethal to aquatic life passing through the mixing zone. Thus, for toxic materials, acute lethality within the mixing zone is a function of concentration and the duration of exposure. Whole effluents should not be acutely lethal to aquatic life, as demonstrated by 96 hour LC_{50} tests done on appropriate species, unless it can be shown either through mixing zone modelling that mixing of the effluent with the receiving water will be achieved in a relatively rapid and complete manner (*e.g.*, no more than a 10% difference in bank-to-bank concentrations within a longitudinal distance of not more than two stream or river widths) or through other scientifically rigorous methods that acute lethality will not occur within the mixing zone;

(iii) Mixing zones should not interfere with the migratory routes essential to the reproduction, growth, or survival of aquatic species;

(iv) Mixing zones should not cause an irreversible organism response, or increase the vulnerability to predation;

(v) When two or more mixing zones are in close proximity, they should be so defined that a continuous passageway for aquatic life is available;

(vi) Mixing zones should not intersect the mouths' of rivers.

(c) Mixing zones should not interfere with spawning and nursery areas;

(d) In lakes and other surface impoundments, the volume of mixing zones should not exceed 10% of the volume of those portions of the receiving waters available for mixing or 100 m in radius, whichever is less;

(e) Mixing zones should not contaminate natural sediments so as to cause or contribute to exceedances of the water quality standards, objectives, and guidelines outside the mixing zone;

(f) Mixing zones should not intersect domestic water supply intakes or bathing areas;

(g) Mixing zones generally do not apply to ground water;

(h) The applicable narrative *Tier III - Water Quality Guidelines* should apply at all points within mixing zones to avoid objectionable nuisance conditions and to protect uses outside mixing zones from unacceptable effects.

TIER II - WATER QUALITY OBJECTIVES

Water Quality Variable	Units and Form	Water Use	Tier II - Water Quality Objectives[a]	Applicable Period	Averaging Duration	Allowable Exceedance Frequency	Design Flow[b]	References
Ammonia	mg/L Total Ammonia as N	Surface Water: Cool Water Aquatic Life and Wildlife	$=\left[\left(\left[\frac{0.0577}{1+10^{7.688-pH}}\right]+\left[\frac{2.487}{1+10^{pH-7.688}}\right]\right)\times a\right]$ (Eq. 1) where a = 2.85 or $=1.45\times10^{0.028\times(25-Temperature)}$ whichever is less and pH ≥6.5 and ≤ 9.0; and $=2.5\times\left[\left(\left[\frac{0.0577}{1+10^{7.688-pH}}\right]+\left[\frac{2.487}{1+10^{pH-7.688}}\right]\right)\times a\right]$ (Eq. 2) where a = 2.85 or $=1.45\times10^{0.028\times(25-Temperature)}$ whichever is less and pH ≥6.5 and ≤ 9.0; and $=\left[\frac{0.411}{1+10^{7.204-pH}}\right]+\left[\frac{58.4}{1+10^{pH-7.204}}\right]$ (Eq. 3) or	Water Temperature >5°C or Early Life Stages are Present Water Temperature >5°C or Early Life Stages are Present All Periods	30 Days[c] 4 Days[c] 1 Hour[d]	Not More Than Once Each 3 Years, On Average Not More Than Once Each 3 Years, On Average Not More Than Once Each 3 Years, On Average	30-Day, 3-Year or 30Q10 4-Day, 3-Year or 7Q10 1-Day, 3-Year or 1Q10	US EPA (1999a)

Water Quality Variable	Units and Form	Water Use	Tier II - Water Quality Objectives[a]	Applicable Period	Averaging Duration	Allowable Exceedance Frequency	Design Flow[b]	References
Ammonia	mg/L Total Ammonia as N	Surface Water: Cool Water Aquatic Life and Wildlife (continued)	$= \left[\left(\left[\frac{0.0577}{1+10^{7.688-pH}}\right]+\left[\frac{2.487}{1+10^{pH-7.688}}\right]\right)\times b\right]$ (Eq. 4) where $b = 1.45\times10^{0.028\times(25-c)}$ and c = Maximum Temperature or 7°C whichever is greater and pH ≥6.5 and ≤ 9.0;	Water Temperature ≤5°C or Early Life Stages are Absent	30 Days[c]	Not More Than Once Each 3 Years, On Average	30-Day, 3-Year or 30Q10	
			and $= 2.5\times\left[\left(\left[\frac{0.0577}{1+10^{7.688-pH}}\right]+\left[\frac{2.487}{1+10^{pH-7.688}}\right]\right)\times b\right]$ (Eq. 5) where $b = 1.45\times10^{0.028\times(25-c)}$ and c = Maximum Temperature or 7°C whichever is greater and pH ≥6.5 and ≤ 9.0;	Water Temperature ≤5°C or Early Life Stages are Absent	4 Days[c]	Not More Than Once Each 3 Years, On Average	4-Day, 3-Year or 7Q10	
			and $= \left[\frac{0.411}{1+10^{7.204-pH}}\right]+\left[\frac{58.4}{1+10^{pH-7.204}}\right]$ (Eq. 6)	All Periods	1 Hour[d]	Not More Than Once Each 3 Years, On Average	1-Day, 3-Year or 1Q10	

Water Quality Variable	Units and Form	Water Use	Tier II - Water Quality Objectives[a]	Applicable Period	Averaging Duration	Allowable Exceedance Frequency	Design Flow[b]	References
Ammonia	mg/L Total Ammonia as N	Surface Water: Cold Water Aquatic Life and Wildlife	$=\left[\left(\left[\frac{0.0577}{1+10^{7.688-pH}}\right]+\left[\frac{2.487}{1+10^{pH-7.688}}\right]\right)\times a\right]$ (Eq. 7) where a = 2.85 or $=1.45\times10^{0.028\times(25-Temperature)}$ whichever is less and pH ≥6.5 and ≤ 9.0; and $=2.5\times\left[\left(\left[\frac{0.0577}{1+10^{7.688-pH}}\right]+\left[\frac{2.487}{1+10^{pH-7.688}}\right]\right)\times a\right]$ (Eq. 8) where a = 2.85 or $=1.45\times10^{0.028\times(25-Temperature)}$ whichever is less and pH ≥6.5 and ≤ 9.0; and $=\left[\frac{0.275}{1+10^{7.204-pH}}\right]+\left[\frac{39.0}{1+10^{pH-7.204}}\right]$ (Eq. 9) or	Early Life Stages are Present	30 Days[c]	Not More Than Once Each 3 Years, On Average	30-Day, 3-Year or 30Q10	US EPA (1999a)
				Early Life Stages are Present	4 Days[c]	Not More Than Once Each 3 Years, On Average	4-Day, 3-Year or 7Q10	
				All Periods	1 Hour[d]	Not More Than Once Each 3 Years, On Average	1-Day, 3-Year or 1Q10	

Water Quality Variable	Units and Form	Water Use	Tier II - Water Quality Objectives[a]	Applicable Period	Averaging Duration	Allowable Exceedance Frequency	Design Flow[b]	References
Ammonia	mg/L Total Ammonia as N	Surface Water: Cold Water Aquatic Life and Wildlife (continued)	$= \left[\left(\left[\frac{0.0577}{1+10^{7.688-pH}}\right]+\left[\frac{2.487}{1+10^{pH-7.688}}\right]\right)\times b\right]$ (Eq. 10) where $b = 1.45\times10^{0.028\times(25-c)}$ and c = Maximum Temperature or 7°C whichever is greater and pH ≥6.5 and ≤ 9.0;	Early Life Stages are Absent	30 Days[c]	Not More Than Once Each 3 Years, On Average	30-Day, 3-Year or 30Q10	
			$= 2.5\times\left[\left(\left[\frac{0.0577}{1+10^{7.688-pH}}\right]+\left[\frac{2.487}{1+10^{pH-7.688}}\right]\right)\times b\right]$ (Eq. 11) where $b = 1.45\times10^{0.028\times(25-c)}$ and c = Maximum Temperature or 7°C whichever is greater and pH ≥6.5 and ≤ 9.0;	Early Life Stages are Absent	4 Days[c]	Not More Than Once Each 3 Years, On Average	4-Day, 3-Year or 7Q10	
			and $= \left[\frac{0.275}{1+10^{7.204-pH}}\right]+\left[\frac{39.0}{1+10^{pH-7.204}}\right]$ (Eq. 12)	All Periods	1 Hour[d]	Not More Than Once Each 3 Years, On Average	1-Day, 3-Year or 1Q10	

Water Quality Variable	Units and Form	Water Use	Tier II - Water Quality Objectives[a]	Applicable Period	Averaging Duration	Allowable Exceedance Frequency	Design Flow[b]	References
Arsenic	µg/L as Dissolved	Surface Water: Aquatic Life and Wildlife	150 and 340	All Periods All Periods	4 Days[c] 1 Hour[d]	Not More Than Once Each 3 Years, On Average Not More Than Once Each 3 Years, On Average	4-Day, 3-Year or 7Q10 1-Day, 3-Year or 1Q10	US EPA (1985a), US EPA (1995), US EPA (1999b)
Cadmium[e]	µg/L as Dissolved	Surface Water: Aquatic Life and Wildlife	$= \left[e^{\{0.7852[\ln(Hardness)]-2.715\}}\right] \times \left[1.101672 - \{\ln(Hardness)(0.041838)\}\right]$ (Eq. 13) where Hardness is expressed in mg/L as $CaCO_3$ and $= \left[e^{\{1.128[\ln(Hardness)]-3.6867\}}\right] \times \left[1.136672 - \{\ln(Hardness)(0.041838)\}\right]$ (Eq. 14) where Hardness is expressed in mg/L as $CaCO_3$	All Periods All Periods	4 Days[c] 1 Hour[d]	Not More Than Once Each 3 Years, On Average Not More Than Once Each 3 Years, On Average	4-Day, 3-Year or 7Q10 1-Day, 3-Year or 1Q10	US EPA (1985b), US EPA (1995), US EPA (1999b)
Chlorine	µg/L as Total Residual	Surface Water: Aquatic Life and Wildlife	11 and 19	All Periods All Periods	4 Days[c] 1 Hour[d]	Not More Than Once Each 3 Years, On Average Not More Than Once Each 3 Years, On Average	4-Day, 3-Year or 7Q10 1-Day, 3-Year or 1Q10	US EPA (1985c), US EPA (1995), US EPA (1999b)

Water Quality Variable	Units and Form	Water Use	Tier II - Water Quality Objectives[a]	Applicable Period	Averaging Duration	Allowable Exceedance Frequency	Design Flow[b]	References
Chromium III[e]	µg/L as Dissolved	Surface Water: Aquatic Life and Wildlife	$=\left[e^{\{0.819[\ln(Hardness)]+0.6848\}}\right]\times[0.860]$ (Eq. 15) where Hardness is expressed in mg/L as $CaCO_3$ and $=\left[e^{\{0.819[\ln(Hardness)]+3.7256\}}\right]\times[0.316]$ (Eq. 16) where Hardness is expressed in mg/L as $CaCO_3$	All Periods All Periods	4 Days[c] 1 Hour[d]	Not More Than Once Each 3 Years, On Average Not More Than Once Each 3 Years, On Average	4-Day, 3-Year or 7Q10 1-Day, 3-Year or 1Q10	US EPA (1985d), US EPA (1995), US EPA (1999b)
Chromium VI	µg/L as Dissolved	Surface Water: Aquatic Life and Wildlife	11 and 16	All Periods All Periods	4 Days[c] 1 Hour[d]	Not More Than Once Each 3 Years, On Average Not More Than Once Each 3 Years, On Average	4-Day, 3-Year or 7Q10 1-Day, 3-Year or 1Q10	US EPA (1985d), US EPA (1995), US EPA (1999b)
Copper[e]	µg/L as Dissolved	Surface Water: Aquatic Life and Wildlife	$=\left[e^{\{0.8545[\ln(Hardness)]-1.702\}}\right]\times[0.960]$ (Eq. 17) where Hardness is expressed in mg/L as $CaCO_3$ and $=\left[e^{\{0.9422[\ln(Hardness)]-1.700\}}\right]\times[0.960]$ (Eq. 18) where Hardness is expressed in mg/L as $CaCO_3$	All Periods All Periods	4 Days[c] 1 Hour[d]	Not More Than Once Each 3 Years, On Average Not More Than Once Each 3 Years, On Average	4-Day, 3-Year or 7Q10 1-Day, 3-Year or 1Q10	US EPA (1985e), US EPA (1995), US EPA (1999b)
Cyanide	µg/L as Weak Acid Dissociable	Surface Water: Aquatic Life and Wildlife	5.2 and 22	All Periods All Periods	4 Days[c] 1 Hour[d]	Not More Than Once Each 3 Years, On Average Not More Than Once Each 3 Years, On Average	4-Day, 3-Year or 7Q10 1-Day, 3-Year or 1Q10	US EPA (1985f), US EPA (1995), US EPA (1999b)

Water Quality Variable	Units and Form	Water Use	Tier II - Water Quality Objectives[a]	Applicable Period	Averaging Duration	Allowable Exceedance Frequency	Design Flow[b]	References
Dissolved Oxygen	mg/L	Surface Water: Cool Water Aquatic Life and Wildlife	5.5	Mature Life Stages[f] (*e.g.*, Water Temperature ≤5°C)	30 Days	Not More Than Once Each 3 Years, On Average	30-Day, 3-Year or 30Q10	US EPA (1986), US EPA (1999b)
			and					
			6.0	Early Life Stages[g] (*e.g.*, Water Temperature >5°C)	7 Days	Not More Than Once Each 3 Years, On Average	7-Day, 3-Year or 7Q10	
			and					
			4.0	Mature Life Stages (*e.g.*, Water Temperature ≤5°C)	7 Day Minimum	Not More Than Once Each 3 Years, On Average	7-Day, 3-Year or 7Q10	
			and					
			5.0	Early Life Stages (*e.g.*, Water Temperature >5°C)	Instantaneous Minimum	Not More Than Once Each 3 Years, On Average	1-Day, 3-Year or 1Q10	
			and					
			3.0	Mature Life Stages (*e.g.*, Water Temperature ≤5°C)	Instantaneous Minimum	Not More Than Once Each 3 Years, On Average	1-Day, 3-Year or 1Q10	

Water Quality Variable	Units and Form	Water Use	Tier II - Water Quality Objectives[a]	Applicable Period	Averaging Duration	Allowable Exceedance Frequency	Design Flow[b]	References
Dissolved Oxygen	mg/L	Surface Water: Cold Water Aquatic Life and Wildlife	6.5 and 9.5 (to achieve 6.5 in intergravel)	Mature Life Stages (*e.g.*, Water Temperature >5°C) Early Life Stages (*e.g.*, Water Temperature ≤5°C)	30 Days 7 Days	Not More Than Once Each 3 Years, On Average Not More Than Once Each 3 Years, On Average	30-Day, 3-Year or 30Q10 7-Day, 3-Year or 7Q10	US EPA (1986), US EPA (1999b)
			5.0 and 8.0 (to achieve 5.0 in intergravel)	Mature Life Stages (*e.g.*, Water Temperature >5°C) Early Life Stages (*e.g.*, Water Temperature ≤5°C)	7 Day Minimum Instantaneous Minimum	Not More Than Once Each 3 Years, On Average Not More Than Once Each 3 Years, On Average	7-Day, 3-Year or 7Q10 1-Day, 3-Year or 1Q10	
			4.0	Mature Life Stages (*e.g.*, Water Temperature >5°C)	Instantaneous Minimum	Not More Than Once Each 3 Years, On Average	1-Day, 3-Year or 1Q10	
Fecal Coliform Bacteria or *Escherichia coli*	Colony Forming Units / 100 mL	Surface Water: Primary Recreation	200	Recreational Season (May 1 to September 30)	1 Day	Not Applicable[h]	7Q10	Williamson (1988b), Health and Welfare Canada (1992)

Water Quality Variable	Units and Form	Water Use	Tier II - Water Quality Objectives[a]	Applicable Period	Averaging Duration	Allowable Exceedance Frequency	Design Flow[b]	References
Fecal Coliform Bacteria or *Escherichia coli*	Colony Forming Units / 100 mL	Surface and Ground Water: Greenhouse Irrigation	200	All Periods When Greenhouse Irrigation is Likely to Occur and When Workers or the Public May Come in Contact With Irrigation Water[i]	1 Day	Not Applicable[h]	7Q10	Williamson (1988b), Health and Welfare Canada (1992)
Fecal Coliform Bacteria or *Escherichia coli*	Colony Forming Units / 100 mL	Surface and Ground Water: Field Crop Irrigation	200	Irrigation Season (May 1 to September 30 and When Workers or the Public May Come in Contact With Irrigation Water	1 Day	Not Applicable[h]	7Q10	Williamson (1988b), Health and Welfare Canada (1992)
Fecal Coliform Bacteria or *Escherichia coli*	Colony Forming Units / 100 mL	Ground Water: Drinking Water	0	All Periods	Not To Be Exceeded	Not To Be Exceeded	Not Applicable	Health and Welfare Canada (1996)

Water Quality Variable	Units and Form	Water Use	Tier II - Water Quality Objectives[a]	Applicable Period	Averaging Duration	Allowable Exceedance Frequency	Design Flow[b]	References
Lead[e]	µg/L as Dissolved	Surface Water: Aquatic Life and Wildlife	$= \left[e^{1.273[\ln(Hardness)]-4.705}\right] \times \left[1.46203 - \{\ln(Hardness)(0.145712)\}\right]$ (Eq. 19) where Hardness is expressed in mg/L as $CaCO_3$ and $= \left[e^{1.273[\ln(Hardness)]-1.460}\right] \times \left[1.46203 - \{\ln(Hardness)(0.145712)\}\right]$ (Eq. 20) where Hardness is expressed in mg/L as $CaCO_3$	All Periods All Periods	4 Days[c] 1 Hour[d]	Not More Than Once Each 3 Years, On Average Not More Than Once Each 3 Years, On Average	4-Day, 3-Year or 7Q10 1-Day, 3-Year or 1Q10	US EPA (1985g), US EPA (1995), US EPA (1999b)
Nickel[e]	µg/L as Dissolved	Surface Water: Aquatic Life and Wildlife	$= \left[e^{[0.8460(\ln(Hardness))+0.0584]}\right] \times [0.997]$ (Eq. 21) where Hardness is expressed in mg/L as $CaCO_3$ and $= \left[e^{[0.8460(\ln(Hardness))+2.255]}\right] \times [0.998]$ (Eq. 22) where Hardness is expressed in mg/L as $CaCO_3$	All Periods All Periods	4 Days[c] 1 Hour[d]	Not More Than Once Each 3 Years, On Average Not More Than Once Each 3 Years, On Average	4-Day, 3-Year or 7Q10 1-Day, 3-Year or 1Q10	US EPA (1985h), US EPA (1995), US EPA (1999b)
Nitrate - Nitrite Nitrogen	mg/L as N	Ground Water: Drinking Water	10	All Periods	Not To Be Exceeded	Not To Be Exceeded	Not Applicable	Health and Welfare Canada (1996)
Sodium Adsorption Ratio	SAR	Surface and Ground Water: Greenhouse Irrigation	4.0	All Periods When Greenhouse Irrigation is Likely to Occur	Not Applicable[h]	Not Applicable[h]	7Q10	National Academy of Sciences / National Academy of Engineering (1973), CCREM (1987)

Water Quality Variable	Units and Form	Water Use	Tier II - Water Quality Objectives[a]	Applicable Period	Averaging Duration	Allowable Exceedance Frequency	Design Flow[b]	References
Sodium Adsorption Ratio	SAR	Surface and Ground Water: Field Crop Irrigation	6.0	All Periods When Field Crop Irrigation is Likely to Occur	7 Days	Not Applicable[h]	7Q10	National Academy of Sciences / National Academy of Engineering (1973), CCREM (1987)

Water Quality Variable	Units and Form	Water Use	Tier II - Water Quality Objectives[a]	Applicable Period	Averaging Duration	Allowable Exceedance Frequency	Design Flow[b]	References
Temperature	°C	Surface Water: Aquatic Life and Wildlife	Site specific objectives will be developed considering the following:					US EPA (1976), US EPA (1999b)
			(1) Thermal additions should be such that thermal stratification and subsequent turnover dates are not altered from those existing prior to the addition of heat from artificial origin.	All Periods				
			(2) One limit which consists of a maximum weekly average temperature (MWAT) that:		7 Days	Not More Than Once Each 3 Years, On Average	4-Day, 3-Year or 7Q10	
			(a) In the warmer months is determined by adding to the physiological optimum temperature (usually for growth) a factor calculated as one-third of the difference between the ultimate upper incipient lethal temperature and the optimum temperature for the most sensitive important species (and appropriate life stages) that normally is found at that location and time; and	Warmer Months				
			(b) In the colder months is an elevated temperature that would still ensure that important species would survive if the temperature suddenly dropped to the normal ambient temperature; or	Colder Months				
			(c) During reproduction seasons meets specific site requirements for successful migration, spawning, egg incubation, and other reproductive functions of important species; or	Reproduction Season				
			(d) At a specific site is found necessary to preserve normal species diversity or prevent undesirable growths of nuisance organisms.	All Periods				
			(3) A second limit which is the time-dependent maximum temperature for short exposures.	All Periods	Site-Specific or Regional-Specific		1-Day, 3-Year or 1Q10	
			(4) Maximum limits may be specified for incremental temperature fluctuations necessary to protect aquatic life from sudden temperature changes.	All Periods	Site-Specific or Regional-Specific			

Water Quality Variable	Units and Form	Water Use	Tier II - Water Quality Objectives[a]	Applicable Period	Averaging Duration	Allowable Exceedance Frequency	Design Flow[b]	References
Total Dissolved Solids or Conductivity	mg/L µS/cm	Surface and Ground Water: Greenhouse Irrigation	700 1000	All Periods When Greenhouse Irrigation is Likely to Occur	7 Days	Not Applicable[h]	7Q10	CCREM (1987)
Total Dissolved Solids or Conductivity	mg/L µS/cm	Surface and Ground Water: Field Crop Irrigation	1000 1500	All Periods When Field Crop Irrigation is Likely to Occur	7 Days	Not Applicable[h]	7Q10	CCREM (1987)
Total Suspended Sediment	mg/L	Surface Water: Aquatic Life and Wildlife	5 mg/L Induced Change from Background[d] and	Background Total Suspended Sediment ≤25 mg/L	30 Days	Not More Than Once Each 3 Years, On Average	30-Day, 3-Year or 30Q10	B.C. Environment (1998)
			25 mg/L Induced Change from Background and	Background Total Suspended Sediment ≤250mg/L	1 Day	Not More Than Once Each 3 Years, On Average	1-Day, 3-Year or 1Q10	
or			10% Induced Change from Background	Background Total Suspended Sediment >250 mg/L	1 Day	Not More Than Once Each 3 Years, On Average	1-Day, 3-Year or 1Q10	
Turbidity	NTU		Equivalent Induced Levels of Change as Calculated From Site-Specific or Regional-Specific Correlation Between Total Suspended Sediment and Turbidity					

Water Quality Variable	Units and Form	Water Use	Tier II - Water Quality Objectives[a]	Applicable Period	Averaging Duration	Allowable Exceedance Frequency	Design Flow[b]	References
Zinc[e]	µg/L as Dissolved	Surface Water: Aquatic Life and Wildlife	$= \left[e^{(0.847[\ln(Hardness)]+0.884)}\right] \times [0.986]$ (Eq. 23) where Hardness is expressed in mg/L as $CaCO_3$ and $= \left[e^{(0.847[\ln(Hardness)]+0.884)}\right] \times [0.978]$ (Eq. 24) where Hardness is expressed in mg/L as $CaCO_3$	All Periods All Periods	4 Days[c] 1 Hour[d]	Not More Than Once Each 3 Years, On Average Not More Than Once Each 3 Years, On Average	4-Day, 3-Year or 7Q10 1-Day, 3-Year or 1Q10	US EPA (1985i), US EPA (1995), US EPA (1999b)

Notes:

a All calculations are available in the linked Excel spreadsheet MWQSOG 2001 CALCULATIONS.XLS and example output is shown for ammonia in Table 1 and for metals in Table 2.

b See Minimum Design Flows and Levels for additional guidance.

c This is analogous to US EPA's Criterion Continuous Concentration (CCC) to prevent chronic effects.

d This is analogous to US EPA's Criterion Maximum Concentration (CMC) to prevent acute effects.

e *Tier II - Water Quality Objectives* for most metals are comprised of two factors - the first represents the toxicity of the total recoverable form of the metal and, when necessary, expressed as a relationship with hardness. This is then multiplied by a second factor to convert the final *Tier II - Water Quality Objective* to a dissolved metal fraction.

f Includes all other life stages other than those defined as "Early Life Stages".

g Includes all embryonic and larval stages and all juvenile forms within 30 days of hatching.

h There is no defined allowable exceedance frequency. Exceedance frequency, however, is governed by the design flow.

i This is analogous to exposure during primary recreation and, therefore, similar *Tier II - Water Quality Objectives* should apply.

j Historical, pre-development concentrations, the upstream concentration existing at any given time, or when necessary, the concentration in an adjacent, undisturbed water body with similar hydrological and geological properties.

Table 1. Matrix showing *Tier II - Water Quality Objectives* for ammonia at pH increments of 0.1 units between 6.50 and 9.00 and at temperature increments of 5°C between 0°C and 30°C.

pH	Temperature	Equation 1 (Ammonia - Chronic; Early Life Stages Present) mg/L	Equation 2 (Ammonia - Chronic; Early Life Stages Present) mg/L	Equation 3 (Ammonia - Acute; All Periods) mg/L	Equation 4 (Ammonia - Chronic; Early Life Stages Absent) mg/L	Equation 5 (Ammonia - Chronic; Early Life Stages Absent) mg/L	Equation 6 (Ammonia - Acute; All Periods) mg/L	Equation 7 (Ammonia - Chronic; Early Life Stages Present) mg/L	Equation 8 (Ammonia - Chronic; Early Life Stages Present) mg/L	Equation 9 (Ammonia - Acute; All Periods) mg/L	Equation 10 (Ammonia - Chronic; Early Life Stages Absent) mg/L	Equation 11 (Ammonia - Chronic; Early Life Stages Absent) mg/L	Equation 12 (Ammonia - Acute; All Periods) mg/L
6.50	0.0	6.67	16.67	48.83	10.82	27.06	48.83	6.67	16.67	32.61	10.82	27.06	32.61
6.60	0.0	6.57	16.41	46.84	10.66	26.65	46.84	6.57	16.41	31.28	10.66	26.65	31.28
6.70	0.0	6.44	16.11	44.57	10.46	26.15	44.57	6.44	16.11	29.76	10.46	26.15	29.76
6.80	0.0	6.29	15.74	42.00	10.22	25.55	42.00	6.29	15.74	28.05	10.22	25.55	28.05
6.90	0.0	6.12	15.29	39.16	9.93	24.84	39.16	6.12	15.29	26.15	9.93	24.84	26.15
7.00	0.0	5.91	14.77	36.09	9.60	23.99	36.09	5.91	14.77	24.10	9.60	23.99	24.10
7.10	0.0	5.67	14.17	32.86	9.20	23.00	32.86	5.67	14.17	21.94	9.20	23.00	21.94
7.20	0.0	5.39	13.47	29.54	8.75	21.88	29.54	5.39	13.47	19.73	8.75	21.88	19.73
7.30	0.0	5.08	12.69	26.21	8.24	20.61	26.21	5.08	12.69	17.51	8.24	20.61	17.51
7.40	0.0	4.73	11.83	22.97	7.69	19.22	22.97	4.73	11.83	15.34	7.69	19.22	15.34
7.50	0.0	4.36	10.91	19.89	7.09	17.72	19.89	4.36	10.91	13.28	7.09	17.72	13.28
7.60	0.0	3.98	9.94	17.03	6.46	16.14	17.03	3.98	9.94	11.37	6.46	16.14	11.37
7.70	0.0	3.58	8.95	14.44	5.81	14.53	14.44	3.58	8.95	9.64	5.81	14.53	9.64
7.80	0.0	3.18	7.96	12.14	5.17	12.92	12.14	3.18	7.96	8.11	5.17	12.92	8.11
7.90	0.0	2.80	6.99	10.13	4.54	11.36	10.13	2.80	6.99	6.77	4.54	11.36	6.77
8.00	0.0	2.43	6.08	8.41	3.95	9.88	8.41	2.43	6.08	5.62	3.95	9.88	5.62
8.10	0.0	2.10	5.24	6.95	3.41	8.51	6.95	2.10	5.24	4.64	3.41	8.51	4.64
8.20	0.0	1.79	4.48	5.73	2.91	7.28	5.73	1.79	4.48	3.83	2.91	7.28	3.83
8.30	0.0	1.52	3.81	4.71	2.47	6.19	4.71	1.52	3.81	3.15	2.47	6.19	3.15
8.40	0.0	1.29	3.22	3.88	2.09	5.24	3.88	1.29	3.22	2.59	2.09	5.24	2.59
8.50	0.0	1.09	2.72	3.20	1.77	4.42	3.20	1.09	2.72	2.14	1.77	4.42	2.14
8.60	0.0	0.92	2.30	2.65	1.49	3.73	2.65	0.92	2.30	1.77	1.49	3.73	1.77
8.70	0.0	0.78	1.95	2.20	1.26	3.16	2.20	0.78	1.95	1.47	1.26	3.16	1.47
8.80	0.0	0.66	1.65	1.84	1.07	2.68	1.84	0.66	1.65	1.23	1.07	2.68	1.23
8.90	0.0	0.56	1.41	1.56	0.92	2.29	1.56	0.56	1.41	1.04	0.92	2.29	1.04
9.00	0.0	0.49	1.22	1.32	0.79	1.97	1.32	0.49	1.22	0.88	0.79	1.97	0.88

Table 1. Continued.

pH	Temperature	Equation 1 (Ammonia - Chronic; Early Life Stages Present) mg/L	Equation 2 (Ammonia - Chronic; Early Life Stages Present) mg/L	Equation 3 (Ammonia - Acute; All Periods) mg/L	Equation 4 (Ammonia - Chronic; Early Life Stages Absent) mg/L	Equation 5 (Ammonia - Chronic; Early Life Stages Absent) mg/L	Equation 6 (Ammonia - Acute; All Periods) mg/L	Equation 7 (Ammonia - Chronic; Early Life Stages Present) mg/L	Equation 8 (Ammonia - Chronic; Early Life Stages Present) mg/L	Equation 9 (Ammonia - Acute; All Periods) mg/L	Equation 10 (Ammonia - Chronic; Early Life Stages Absent) mg/L	Equation 11 (Ammonia - Chronic; Early Life Stages Absent) mg/L	Equation 12 (Ammonia - Acute; All Periods) mg/L
6.50	5.0	6.67	16.67	48.83	10.82	27.06	48.83	6.67	16.67	32.61	10.82	27.06	32.61
6.60	5.0	6.57	16.41	46.84	10.66	26.65	46.84	6.57	16.41	31.28	10.66	26.65	31.28
6.70	5.0	6.44	16.11	44.57	10.46	26.15	44.57	6.44	16.11	29.76	10.46	26.15	29.76
6.80	5.0	6.29	15.74	42.00	10.22	25.55	42.00	6.29	15.74	28.05	10.22	25.55	28.05
6.90	5.0	6.12	15.29	39.16	9.93	24.84	39.16	6.12	15.29	26.15	9.93	24.84	26.15
7.00	5.0	5.91	14.77	36.09	9.60	23.99	36.09	5.91	14.77	24.10	9.60	23.99	24.10
7.10	5.0	5.67	14.17	32.86	9.20	23.00	32.86	5.67	14.17	21.94	9.20	23.00	21.94
7.20	5.0	5.39	13.47	29.54	8.75	21.88	29.54	5.39	13.47	19.73	8.75	21.88	19.73
7.30	5.0	5.08	12.69	26.21	8.24	20.61	26.21	5.08	12.69	17.51	8.24	20.61	17.51
7.40	5.0	4.73	11.83	22.97	7.69	19.22	22.97	4.73	11.83	15.34	7.69	19.22	15.34
7.50	5.0	4.36	10.91	19.89	7.09	17.72	19.89	4.36	10.91	13.28	7.09	17.72	13.28
7.60	5.0	3.98	9.94	17.03	6.46	16.14	17.03	3.98	9.94	11.37	6.46	16.14	11.37
7.70	5.0	3.58	8.95	14.44	5.81	14.53	14.44	3.58	8.95	9.64	5.81	14.53	9.64
7.80	5.0	3.18	7.96	12.14	5.17	12.92	12.14	3.18	7.96	8.11	5.17	12.92	8.11
7.90	5.0	2.80	6.99	10.13	4.54	11.36	10.13	2.80	6.99	6.77	4.54	11.36	6.77
8.00	5.0	2.43	6.08	8.41	3.95	9.88	8.41	2.43	6.08	5.62	3.95	9.88	5.62
8.10	5.0	2.10	5.24	6.95	3.41	8.51	6.95	2.10	5.24	4.64	3.41	8.51	4.64
8.20	5.0	1.79	4.48	5.73	2.91	7.28	5.73	1.79	4.48	3.83	2.91	7.28	3.83
8.30	5.0	1.52	3.81	4.71	2.47	6.19	4.71	1.52	3.81	3.15	2.47	6.19	3.15
8.40	5.0	1.29	3.22	3.88	2.09	5.24	3.88	1.29	3.22	2.59	2.09	5.24	2.59
8.50	5.0	1.09	2.72	3.20	1.77	4.42	3.20	1.09	2.72	2.14	1.77	4.42	2.14
8.60	5.0	0.92	2.30	2.65	1.49	3.73	2.65	0.92	2.30	1.77	1.49	3.73	1.77
8.70	5.0	0.78	1.95	2.20	1.26	3.16	2.20	0.78	1.95	1.47	1.26	3.16	1.47
8.80	5.0	0.66	1.65	1.84	1.07	2.68	1.84	0.66	1.65	1.23	1.07	2.68	1.23
8.90	5.0	0.56	1.41	1.56	0.92	2.29	1.56	0.56	1.41	1.04	0.92	2.29	1.04
9.00	5.0	0.49	1.22	1.32	0.79	1.97	1.32	0.49	1.22	0.88	0.79	1.97	0.88

Table 1. Continued.

pH	Temperature	Equation 1 (Ammonia - Chronic; Early Life Stages Present) mg/L	Equation 2 (Ammonia - Chronic; Early Life Stages Present) mg/L	Equation 3 (Ammonia - Acute; All Periods) mg/L	Equation 4 (Ammonia - Chronic; Early Life Stages Absent) mg/L	Equation 5 (Ammonia - Chronic; Early Life Stages Absent) mg/L	Equation 6 (Ammonia - Acute; All Periods) mg/L	Equation 7 (Ammonia - Chronic; Early Life Stages Present) mg/L	Equation 8 (Ammonia - Chronic; Early Life Stages Present) mg/L	Equation 9 (Ammonia - Acute; All Periods) mg/L	Equation 10 (Ammonia - Chronic; Early Life Stages Absent) mg/L	Equation 11 (Ammonia - Chronic; Early Life Stages Absent) mg/L	Equation 12 (Ammonia - Acute; All Periods) mg/L
6.50	10.0	6.67	16.67	48.83	8.92	22.30	48.83	6.67	16.67	32.61	8.92	22.30	32.61
6.60	10.0	6.57	16.41	46.84	8.79	21.96	46.84	6.57	16.41	31.28	8.79	21.96	31.28
6.70	10.0	6.44	16.11	44.57	8.62	21.55	44.57	6.44	16.11	29.76	8.62	21.55	29.76
6.80	10.0	6.29	15.74	42.00	8.42	21.06	42.00	6.29	15.74	28.05	8.42	21.06	28.05
6.90	10.0	6.12	15.29	39.16	8.19	20.47	39.16	6.12	15.29	26.15	8.19	20.47	26.15
7.00	10.0	5.91	14.77	36.09	7.91	19.77	36.09	5.91	14.77	24.10	7.91	19.77	24.10
7.10	10.0	5.67	14.17	32.86	7.58	18.96	32.86	5.67	14.17	21.94	7.58	18.96	21.94
7.20	10.0	5.39	13.47	29.54	7.21	18.03	29.54	5.39	13.47	19.73	7.21	18.03	19.73
7.30	10.0	5.08	12.69	26.21	6.79	16.99	26.21	5.08	12.69	17.51	6.79	16.99	17.51
7.40	10.0	4.73	11.83	22.97	6.33	15.84	22.97	4.73	11.83	15.34	6.33	15.84	15.34
7.50	10.0	4.36	10.91	19.89	5.84	14.60	19.89	4.36	10.91	13.28	5.84	14.60	13.28
7.60	10.0	3.98	9.94	17.03	5.32	13.30	17.03	3.98	9.94	11.37	5.32	13.30	11.37
7.70	10.0	3.58	8.95	14.44	4.79	11.97	14.44	3.58	8.95	9.64	4.79	11.97	9.64
7.80	10.0	3.18	7.96	12.14	4.26	10.65	12.14	3.18	7.96	8.11	4.26	10.65	8.11
7.90	10.0	2.80	6.99	10.13	3.74	9.36	10.13	2.80	6.99	6.77	3.74	9.36	6.77
8.00	10.0	2.43	6.08	8.41	3.26	8.14	8.41	2.43	6.08	5.62	3.26	8.14	5.62
8.10	10.0	2.10	5.24	6.95	2.81	7.02	6.95	2.10	5.24	4.64	2.81	7.02	4.64
8.20	10.0	1.79	4.48	5.73	2.40	6.00	5.73	1.79	4.48	3.83	2.40	6.00	3.83
8.30	10.0	1.52	3.81	4.71	2.04	5.10	4.71	1.52	3.81	3.15	2.04	5.10	3.15
8.40	10.0	1.29	3.22	3.88	1.73	4.32	3.88	1.29	3.22	2.59	1.73	4.32	2.59
8.50	10.0	1.09	2.72	3.20	1.46	3.64	3.20	1.09	2.72	2.14	1.46	3.64	2.14
8.60	10.0	0.92	2.30	2.65	1.23	3.08	2.65	0.92	2.30	1.77	1.23	3.08	1.77
8.70	10.0	0.78	1.95	2.20	1.04	2.60	2.20	0.78	1.95	1.47	1.04	2.60	1.47
8.80	10.0	0.66	1.65	1.84	0.88	2.21	1.84	0.66	1.65	1.23	0.88	2.21	1.23
8.90	10.0	0.56	1.41	1.56	0.76	1.89	1.56	0.56	1.41	1.04	0.76	1.89	1.04
9.00	10.0	0.49	1.22	1.32	0.65	1.63	1.32	0.49	1.22	0.88	0.65	1.63	0.88

Table 1. Continued.

pH	Temperature	Equation 1 (Ammonia - Chronic; Early Life Stages Present) mg/L	Equation 2 (Ammonia - Chronic; Early Life Stages Present) mg/L	Equation 3 (Ammonia - Acute; All Periods) mg/L	Equation 4 (Ammonia - Chronic; Early Life Stages Absent) mg/L	Equation 5 (Ammonia - Chronic; Early Life Stages Absent) mg/L	Equation 6 (Ammonia - Acute; All Periods) mg/L	Equation 7 (Ammonia - Chronic; Early Life Stages Present) mg/L	Equation 8 (Ammonia - Chronic; Early Life Stages Present) mg/L	Equation 9 (Ammonia - Acute; All Periods) mg/L	Equation 10 (Ammonia - Chronic; Early Life Stages Absent) mg/L	Equation 11 (Ammonia - Chronic; Early Life Stages Absent) mg/L	Equation 12 (Ammonia - Acute; All Periods) mg/L
6.50	15.0	6.46	16.16	48.83	6.46	16.16	48.83	6.46	16.16	32.61	6.46	16.16	32.61
6.60	15.0	6.36	15.91	46.84	6.36	15.91	46.84	6.36	15.91	31.28	6.36	15.91	31.28
6.70	15.0	6.25	15.61	44.57	6.25	15.61	44.57	6.25	15.61	29.76	6.25	15.61	29.76
6.80	15.0	6.10	15.26	42.00	6.10	15.26	42.00	6.10	15.26	28.05	6.10	15.26	28.05
6.90	15.0	5.93	14.83	39.16	5.93	14.83	39.16	5.93	14.83	26.15	5.93	14.83	26.15
7.00	15.0	5.73	14.32	36.09	5.73	14.32	36.09	5.73	14.32	24.10	5.73	14.32	24.10
7.10	15.0	5.49	13.73	32.86	5.49	13.73	32.86	5.49	13.73	21.94	5.49	13.73	21.94
7.20	15.0	5.22	13.06	29.54	5.22	13.06	29.54	5.22	13.06	19.73	5.22	13.06	19.73
7.30	15.0	4.92	12.31	26.21	4.92	12.31	26.21	4.92	12.31	17.51	4.92	12.31	17.51
7.40	15.0	4.59	11.47	22.97	4.59	11.47	22.97	4.59	11.47	15.34	4.59	11.47	15.34
7.50	15.0	4.23	10.58	19.89	4.23	10.58	19.89	4.23	10.58	13.28	4.23	10.58	13.28
7.60	15.0	3.85	9.64	17.03	3.85	9.64	17.03	3.85	9.64	11.37	3.85	9.64	11.37
7.70	15.0	3.47	8.67	14.44	3.47	8.67	14.44	3.47	8.67	9.64	3.47	8.67	9.64
7.80	15.0	3.09	7.71	12.14	3.09	7.71	12.14	3.09	7.71	8.11	3.09	7.71	8.11
7.90	15.0	2.71	6.78	10.13	2.71	6.78	10.13	2.71	6.78	6.77	2.71	6.78	6.77
8.00	15.0	2.36	5.90	8.41	2.36	5.90	8.41	2.36	5.90	5.62	2.36	5.90	5.62
8.10	15.0	2.03	5.08	6.95	2.03	5.08	6.95	2.03	5.08	4.64	2.03	5.08	4.64
8.20	15.0	1.74	4.35	5.73	1.74	4.35	5.73	1.74	4.35	3.83	1.74	4.35	3.83
8.30	15.0	1.48	3.69	4.71	1.48	3.69	4.71	1.48	3.69	3.15	1.48	3.69	3.15
8.40	15.0	1.25	3.13	3.88	1.25	3.13	3.88	1.25	3.13	2.59	1.25	3.13	2.59
8.50	15.0	1.06	2.64	3.20	1.06	2.64	3.20	1.06	2.64	2.14	1.06	2.64	2.14
8.60	15.0	0.89	2.23	2.65	0.89	2.23	2.65	0.89	2.23	1.77	0.89	2.23	1.77
8.70	15.0	0.75	1.89	2.20	0.75	1.89	2.20	0.75	1.89	1.47	0.75	1.89	1.47
8.80	15.0	0.64	1.60	1.84	0.64	1.60	1.84	0.64	1.60	1.23	0.64	1.60	1.23
8.90	15.0	0.55	1.37	1.56	0.55	1.37	1.56	0.55	1.37	1.04	0.55	1.37	1.04
9.00	15.0	0.47	1.18	1.32	0.47	1.18	1.32	0.47	1.18	0.88	0.47	1.18	0.88

Table 1. Continued.

pH	Temperature	Equation 1 (Ammonia - Chronic; Early Life Stages Present) mg/L	Equation 2 (Ammonia - Chronic; Early Life Stages Present) mg/L	Equation 3 (Ammonia - Acute; All Periods) mg/L	Equation 4 (Ammonia - Chronic; Early Life Stages Absent) mg/L	Equation 5 (Ammonia - Chronic; Early Life Stages Absent) mg/L	Equation 6 (Ammonia - Acute; All Periods) mg/L	Equation 7 (Ammonia - Chronic; Early Life Stages Present) mg/L	Equation 8 (Ammonia - Chronic; Early Life Stages Present) mg/L	Equation 9 (Ammonia - Acute; All Periods) mg/L	Equation 10 (Ammonia - Chronic; Early Life Stages Absent) mg/L	Equation 11 (Ammonia - Chronic; Early Life Stages Absent) mg/L	Equation 12 (Ammonia - Acute; All Periods) mg/L
6.50	20.0	4.68	11.70	48.83	4.68	11.70	48.83	4.68	11.70	32.61	4.68	11.70	32.61
6.60	20.0	4.61	11.53	46.84	4.61	11.53	46.84	4.61	11.53	31.28	4.61	11.53	31.28
6.70	20.0	4.52	11.31	44.57	4.52	11.31	44.57	4.52	11.31	29.76	4.52	11.31	29.76
6.80	20.0	4.42	11.05	42.00	4.42	11.05	42.00	4.42	11.05	28.05	4.42	11.05	28.05
6.90	20.0	4.30	10.74	39.16	4.30	10.74	39.16	4.30	10.74	26.15	4.30	10.74	26.15
7.00	20.0	4.15	10.38	36.09	4.15	10.38	36.09	4.15	10.38	24.10	4.15	10.38	24.10
7.10	20.0	3.98	9.95	32.86	3.98	9.95	32.86	3.98	9.95	21.94	3.98	9.95	21.94
7.20	20.0	3.78	9.46	29.54	3.78	9.46	29.54	3.78	9.46	19.73	3.78	9.46	19.73
7.30	20.0	3.57	8.91	26.21	3.57	8.91	26.21	3.57	8.91	17.51	3.57	8.91	17.51
7.40	20.0	3.32	8.31	22.97	3.32	8.31	22.97	3.32	8.31	15.34	3.32	8.31	15.34
7.50	20.0	3.06	7.66	19.89	3.06	7.66	19.89	3.06	7.66	13.28	3.06	7.66	13.28
7.60	20.0	2.79	6.98	17.03	2.79	6.98	17.03	2.79	6.98	11.37	2.79	6.98	11.37
7.70	20.0	2.51	6.28	14.44	2.51	6.28	14.44	2.51	6.28	9.64	2.51	6.28	9.64
7.80	20.0	2.23	5.59	12.14	2.23	5.59	12.14	2.23	5.59	8.11	2.23	5.59	8.11
7.90	20.0	1.96	4.91	10.13	1.96	4.91	10.13	1.96	4.91	6.77	1.96	4.91	6.77
8.00	20.0	1.71	4.27	8.41	1.71	4.27	8.41	1.71	4.27	5.62	1.71	4.27	5.62
8.10	20.0	1.47	3.68	6.95	1.47	3.68	6.95	1.47	3.68	4.64	1.47	3.68	4.64
8.20	20.0	1.26	3.15	5.73	1.26	3.15	5.73	1.26	3.15	3.83	1.26	3.15	3.83
8.30	20.0	1.07	2.68	4.71	1.07	2.68	4.71	1.07	2.68	3.15	1.07	2.68	3.15
8.40	20.0	0.91	2.26	3.88	0.91	2.26	3.88	0.91	2.26	2.59	0.91	2.26	2.59
8.50	20.0	0.76	1.91	3.20	0.76	1.91	3.20	0.76	1.91	2.14	0.76	1.91	2.14
8.60	20.0	0.65	1.61	2.65	0.65	1.61	2.65	0.65	1.61	1.77	0.65	1.61	1.77
8.70	20.0	0.55	1.37	2.20	0.55	1.37	2.20	0.55	1.37	1.47	0.55	1.37	1.47
8.80	20.0	0.46	1.16	1.84	0.46	1.16	1.84	0.46	1.16	1.23	0.46	1.16	1.23
8.90	20.0	0.40	0.99	1.56	0.40	0.99	1.56	0.40	0.99	1.04	0.40	0.99	1.04
9.00	20.0	0.34	0.85	1.32	0.34	0.85	1.32	0.34	0.85	0.88	0.34	0.85	0.88

Table 1. Continued.

pH	Temperature	Equation 1 (Ammonia - Chronic; Early Life Stages Present) mg/L	Equation 2 (Ammonia - Chronic; Early Life Stages Present) mg/L	Equation 3 (Ammonia - Acute; All Periods) mg/L	Equation 4 (Ammonia - Chronic; Early Life Stages Absent) mg/L	Equation 5 (Ammonia - Chronic; Early Life Stages Absent) mg/L	Equation 6 (Ammonia - Acute; All Periods) mg/L	Equation 7 (Ammonia - Chronic; Early Life Stages Present) mg/L	Equation 8 (Ammonia - Chronic; Early Life Stages Present) mg/L	Equation 9 (Ammonia - Acute; All Periods) mg/L	Equation 10 (Ammonia - Chronic; Early Life Stages Absent) mg/L	Equation 11 (Ammonia - Chronic; Early Life Stages Absent) mg/L	Equation 12 (Ammonia - Acute; All Periods) mg/L
6.50	25.0	3.39	8.48	48.83	3.39	8.48	48.83	3.39	8.48	32.61	3.39	8.48	32.61
6.60	25.0	3.34	8.35	46.84	3.34	8.35	46.84	3.34	8.35	31.28	3.34	8.35	31.28
6.70	25.0	3.28	8.19	44.57	3.28	8.19	44.57	3.28	8.19	29.76	3.28	8.19	29.76
6.80	25.0	3.20	8.01	42.00	3.20	8.01	42.00	3.20	8.01	28.05	3.20	8.01	28.05
6.90	25.0	3.11	7.78	39.16	3.11	7.78	39.16	3.11	7.78	26.15	3.11	7.78	26.15
7.00	25.0	3.01	7.52	36.09	3.01	7.52	36.09	3.01	7.52	24.10	3.01	7.52	24.10
7.10	25.0	2.88	7.21	32.86	2.88	7.21	32.86	2.88	7.21	21.94	2.88	7.21	21.94
7.20	25.0	2.74	6.85	29.54	2.74	6.85	29.54	2.74	6.85	19.73	2.74	6.85	19.73
7.30	25.0	2.58	6.46	26.21	2.58	6.46	26.21	2.58	6.46	17.51	2.58	6.46	17.51
7.40	25.0	2.41	6.02	22.97	2.41	6.02	22.97	2.41	6.02	15.34	2.41	6.02	15.34
7.50	25.0	2.22	5.55	19.89	2.22	5.55	19.89	2.22	5.55	13.28	2.22	5.55	13.28
7.60	25.0	2.02	5.06	17.03	2.02	5.06	17.03	2.02	5.06	11.37	2.02	5.06	11.37
7.70	25.0	1.82	4.55	14.44	1.82	4.55	14.44	1.82	4.55	9.64	1.82	4.55	9.64
7.80	25.0	1.62	4.05	12.14	1.62	4.05	12.14	1.62	4.05	8.11	1.62	4.05	8.11
7.90	25.0	1.42	3.56	10.13	1.42	3.56	10.13	1.42	3.56	6.77	1.42	3.56	6.77
8.00	25.0	1.24	3.10	8.41	1.24	3.10	8.41	1.24	3.10	5.62	1.24	3.10	5.62
8.10	25.0	1.07	2.67	6.95	1.07	2.67	6.95	1.07	2.67	4.64	1.07	2.67	4.64
8.20	25.0	0.91	2.28	5.73	0.91	2.28	5.73	0.91	2.28	3.83	0.91	2.28	3.83
8.30	25.0	0.78	1.94	4.71	0.78	1.94	4.71	0.78	1.94	3.15	0.78	1.94	3.15
8.40	25.0	0.66	1.64	3.88	0.66	1.64	3.88	0.66	1.64	2.59	0.66	1.64	2.59
8.50	25.0	0.55	1.39	3.20	0.55	1.39	3.20	0.55	1.39	2.14	0.55	1.39	2.14
8.60	25.0	0.47	1.17	2.65	0.47	1.17	2.65	0.47	1.17	1.77	0.47	1.17	1.77
8.70	25.0	0.40	0.99	2.20	0.40	0.99	2.20	0.40	0.99	1.47	0.40	0.99	1.47
8.80	25.0	0.34	0.84	1.84	0.34	0.84	1.84	0.34	0.84	1.23	0.34	0.84	1.23
8.90	25.0	0.29	0.72	1.56	0.29	0.72	1.56	0.29	0.72	1.04	0.29	0.72	1.04
9.00	25.0	0.25	0.62	1.32	0.25	0.62	1.32	0.25	0.62	0.88	0.25	0.62	0.88

Table 1. Continued.

pH	Temperature	Equation 1 (Ammonia - Chronic; Early Life Stages Present) mg/L	Equation 2 (Ammonia - Chronic; Early Life Stages Present) mg/L	Equation 3 (Ammonia - Acute; All Periods) mg/L	Equation 4 (Ammonia - Chronic; Early Life Stages Absent) mg/L	Equation 5 (Ammonia - Chronic; Early Life Stages Absent) mg/L	Equation 6 (Ammonia - Acute; All Periods) mg/L	Equation 7 (Ammonia - Chronic; Early Life Stages Present) mg/L	Equation 8 (Ammonia - Chronic; Early Life Stages Present) mg/L	Equation 9 (Ammonia - Acute; All Periods) mg/L	Equation 10 (Ammonia - Chronic; Early Life Stages Absent) mg/L	Equation 11 (Ammonia - Chronic; Early Life Stages Absent) mg/L	Equation 12 (Ammonia - Acute; All Periods) mg/L
6.50	30.0	2.46	6.14	48.83	2.46	6.14	48.83	2.46	6.14	32.61	2.46	6.14	32.61
6.60	30.0	2.42	6.05	46.84	2.42	6.05	46.84	2.42	6.05	31.28	2.42	6.05	31.28
6.70	30.0	2.37	5.94	44.57	2.37	5.94	44.57	2.37	5.94	29.76	2.37	5.94	29.76
6.80	30.0	2.32	5.80	42.00	2.32	5.80	42.00	2.32	5.80	28.05	2.32	5.80	28.05
6.90	30.0	2.25	5.64	39.16	2.25	5.64	39.16	2.25	5.64	26.15	2.25	5.64	26.15
7.00	30.0	2.18	5.45	36.09	2.18	5.45	36.09	2.18	5.45	24.10	2.18	5.45	24.10
7.10	30.0	2.09	5.22	32.86	2.09	5.22	32.86	2.09	5.22	21.94	2.09	5.22	21.94
7.20	30.0	1.99	4.97	29.54	1.99	4.97	29.54	1.99	4.97	19.73	1.99	4.97	19.73
7.30	30.0	1.87	4.68	26.21	1.87	4.68	26.21	1.87	4.68	17.51	1.87	4.68	17.51
7.40	30.0	1.74	4.36	22.97	1.74	4.36	22.97	1.74	4.36	15.34	1.74	4.36	15.34
7.50	30.0	1.61	4.02	19.89	1.61	4.02	19.89	1.61	4.02	13.28	1.61	4.02	13.28
7.60	30.0	1.47	3.66	17.03	1.47	3.66	17.03	1.47	3.66	11.37	1.47	3.66	11.37
7.70	30.0	1.32	3.30	14.44	1.32	3.30	14.44	1.32	3.30	9.64	1.32	3.30	9.64
7.80	30.0	1.17	2.93	12.14	1.17	2.93	12.14	1.17	2.93	8.11	1.17	2.93	8.11
7.90	30.0	1.03	2.58	10.13	1.03	2.58	10.13	1.03	2.58	6.77	1.03	2.58	6.77
8.00	30.0	0.90	2.24	8.41	0.90	2.24	8.41	0.90	2.24	5.62	0.90	2.24	5.62
8.10	30.0	0.77	1.93	6.95	0.77	1.93	6.95	0.77	1.93	4.64	0.77	1.93	4.64
8.20	30.0	0.66	1.65	5.73	0.66	1.65	5.73	0.66	1.65	3.83	0.66	1.65	3.83
8.30	30.0	0.56	1.40	4.71	0.56	1.40	4.71	0.56	1.40	3.15	0.56	1.40	3.15
8.40	30.0	0.48	1.19	3.88	0.48	1.19	3.88	0.48	1.19	2.59	0.48	1.19	2.59
8.50	30.0	0.40	1.00	3.20	0.40	1.00	3.20	0.40	1.00	2.14	0.40	1.00	2.14
8.60	30.0	0.34	0.85	2.65	0.34	0.85	2.65	0.34	0.85	1.77	0.34	0.85	1.77
8.70	30.0	0.29	0.72	2.20	0.29	0.72	2.20	0.29	0.72	1.47	0.29	0.72	1.47
8.80	30.0	0.24	0.61	1.84	0.24	0.61	1.84	0.24	0.61	1.23	0.24	0.61	1.23
8.90	30.0	0.21	0.52	1.56	0.21	0.52	1.56	0.21	0.52	1.04	0.21	0.52	1.04
9.00	30.0	0.18	0.45	1.32	0.18	0.45	1.32	0.18	0.45	0.88	0.18	0.45	0.88

Table 2. Matrix showing *Tier II - Water Quality Objectives* for various metals at hardness increments of 5 mg/L between 5 and 400 mg/L.

Hardness mg/L $CaCO_3$	Equation 13 (Cadmium - Chronic) µg/L	Equation 14 (Cadmium - Acute) µg/L	Equation 15 (Chromium III - Chronic) µg/L	Equation 16 (Chromium III - Acute) µg/L	Equation 17 (Copper - Chronic) µg/L	Equation 18 (Copper - Acute) µg/L	Equation 19 (Lead - Chronic) µg/L	Equation 20 (Lead - Acute) µg/L	Equation 21 (Nickel - Chronic) µg/L	Equation 22 (Nickel - Acute) µg/L	Equation 23 (Zinc - Chronic) µg/L	Equation 24 (Zinc - Acute) µg/L
5.00	0.24	0.16	6.37	48.99	0.69	0.80	0.09	2.21	4.12	37.14	9.33	9.26
10.00	0.41	0.35	11.24	86.44	1.25	1.54	0.19	4.91	7.41	66.75	16.79	16.66
15.00	0.55	0.54	15.67	120.48	1.77	2.25	0.30	7.79	10.45	94.07	23.68	23.48
20.00	0.68	0.74	19.84	152.49	2.26	2.95	0.42	10.79	13.33	119.99	30.21	29.97
25.00	0.80	0.95	23.81	183.07	2.74	3.64	0.54	13.88	16.10	144.92	36.50	36.20
30.00	0.92	1.16	27.65	212.55	3.20	4.32	0.66	17.04	18.78	169.09	42.59	42.25
35.00	1.03	1.37	31.37	241.15	3.65	5.00	0.79	20.25	21.40	192.64	48.54	48.14
40.00	1.14	1.58	34.99	269.02	4.09	5.67	0.92	23.51	23.96	215.68	54.35	53.91
45.00	1.24	1.79	38.54	296.26	4.53	6.33	1.04	26.81	26.47	238.28	60.06	59.57
50.00	1.34	2.01	42.01	322.96	4.95	6.99	1.17	30.14	28.93	260.49	65.66	65.13
55.00	1.44	2.23	45.42	349.18	5.37	7.65	1.31	33.49	31.36	282.37	71.19	70.61
60.00	1.53	2.45	48.78	374.97	5.79	8.31	1.44	36.88	33.76	303.93	76.63	76.01
65.00	1.63	2.67	52.08	400.38	6.20	8.96	1.57	40.28	36.12	325.23	82.01	81.35
70.00	1.72	2.90	55.34	425.43	6.60	9.60	1.70	43.71	38.46	346.27	87.33	86.62
75.00	1.81	3.12	58.56	450.16	7.00	10.25	1.84	47.15	40.77	367.08	92.58	91.83
80.00	1.90	3.35	61.74	474.60	7.40	10.89	1.97	50.61	43.06	387.68	97.79	96.99
85.00	1.98	3.58	64.88	498.76	7.79	11.53	2.11	54.08	45.33	408.09	102.94	102.11
90.00	2.07	3.80	67.99	522.66	8.18	12.17	2.24	57.57	47.57	428.31	108.05	107.17
95.00	2.15	4.03	71.07	546.32	8.57	12.81	2.38	61.07	49.80	448.35	113.11	112.20
100.00	2.24	4.26	74.11	569.76	8.96	13.44	2.52	64.58	52.01	468.24	118.14	117.18
105.00	2.32	4.50	77.14	592.99	9.34	14.07	2.65	68.10	54.20	487.97	123.13	122.13
110.00	2.40	4.73	80.13	616.02	9.72	14.70	2.79	71.63	56.37	507.55	128.08	127.04
115.00	2.48	4.96	83.10	638.86	10.09	15.33	2.93	75.17	58.53	527.01	132.99	131.91
120.00	2.56	5.20	86.05	661.52	10.47	15.96	3.07	78.72	60.68	546.33	137.87	136.76
125.00	2.64	5.43	88.98	684.01	10.84	16.58	3.21	82.27	62.81	565.52	142.73	141.57
130.00	2.72	5.67	91.88	706.34	11.21	17.21	3.34	85.83	64.93	584.60	147.55	146.35
135.00	2.79	5.90	94.76	728.51	11.57	17.83	3.48	89.40	67.04	603.57	152.34	151.11
140.00	2.87	6.14	97.63	750.54	11.94	18.45	3.62	92.97	69.13	622.43	157.11	155.84
145.00	2.94	6.38	100.48	772.42	12.30	19.07	3.76	96.55	71.22	641.18	161.85	160.54
150.00	3.02	6.62	103.31	794.17	12.66	19.69	3.90	100.13	73.29	659.84	166.57	165.22
155.00	3.09	6.86	106.12	815.79	13.02	20.31	4.04	103.72	75.35	678.40	171.26	169.87

Table 2. Continued.

Hardness mg/L $CaCO_3$	Equation 13 (Cadmium - Chronic) µg/L	Equation 14 (Cadmium - Acute) µg/L	Equation 15 (Chromium III - Chronic) µg/L	Equation 16 (Chromium III - Acute) µg/L	Equation 17 (Copper - Chronic) µg/L	Equation 18 (Copper - Acute) µg/L	Equation 19 (Lead - Chronic) µg/L	Equation 20 (Lead - Acute) µg/L	Equation 21 (Nickel - Chronic) µg/L	Equation 22 (Nickel - Acute) µg/L	Equation 23 (Zinc - Chronic) µg/L	Equation 24 (Zinc - Acute) µg/L
160.00	3.17	7.10	108.91	837.28	13.38	20.93	4.18	107.31	77.40	696.87	175.93	174.50
165.00	3.24	7.34	111.69	858.65	13.74	21.54	4.32	110.90	79.44	715.25	180.58	179.11
170.00	3.31	7.58	114.46	879.90	14.09	22.16	4.46	114.50	81.47	733.54	185.20	183.70
175.00	3.38	7.82	117.21	901.04	14.45	22.77	4.60	118.10	83.50	751.75	189.81	188.27
180.00	3.45	8.06	119.94	922.07	14.80	23.38	4.74	121.70	85.51	769.88	194.40	192.82
185.00	3.53	8.30	122.66	942.99	15.15	23.99	4.88	125.31	87.52	787.94	198.96	197.35
190.00	3.60	8.55	125.37	963.82	15.50	24.60	5.02	128.92	89.51	805.92	203.51	201.86
195.00	3.66	8.79	128.07	984.54	15.85	25.21	5.16	132.53	91.50	823.82	208.04	206.35
200.00	3.73	9.03	130.75	1005.17	16.19	25.82	5.31	136.14	93.48	841.66	212.55	210.82
205.00	3.80	9.28	133.42	1025.70	16.54	26.43	5.45	139.76	95.46	859.43	217.04	215.28
210.00	3.87	9.52	136.08	1046.15	16.88	27.04	5.59	143.37	97.42	877.13	221.52	219.72
215.00	3.94	9.77	138.73	1066.50	17.23	27.64	5.73	146.99	99.38	894.76	225.98	224.15
220.00	4.01	10.02	141.37	1086.77	17.57	28.25	5.87	150.61	101.33	912.33	230.42	228.55
225.00	4.07	10.26	143.99	1106.96	17.91	28.85	6.01	154.23	103.28	929.85	234.85	232.95
230.00	4.14	10.51	146.61	1127.07	18.25	29.46	6.15	157.85	105.22	947.30	239.27	237.33
235.00	4.21	10.76	149.21	1147.09	18.59	30.06	6.29	161.47	107.15	964.69	243.67	241.69
240.00	4.27	11.00	151.81	1167.05	18.92	30.66	6.43	165.10	109.07	982.03	248.05	246.04
245.00	4.34	11.25	154.39	1186.92	19.26	31.26	6.57	168.72	110.99	999.31	252.43	250.38
250.00	4.40	11.50	156.97	1206.72	19.59	31.86	6.72	172.34	112.91	1016.53	256.78	254.70
255.00	4.47	11.75	159.54	1226.45	19.93	32.46	6.86	175.97	114.81	1033.71	261.13	259.01
260.00	4.53	12.00	162.09	1246.11	20.26	33.06	7.00	179.59	116.71	1050.83	265.46	263.31
265.00	4.59	12.25	164.64	1265.71	20.60	33.66	7.14	183.22	118.61	1067.90	269.78	267.59
270.00	4.66	12.50	167.18	1285.23	20.93	34.26	7.28	186.84	120.50	1084.92	274.09	271.86
275.00	4.72	12.75	169.71	1304.69	21.26	34.86	7.42	190.47	122.39	1101.89	278.38	276.12
280.00	4.78	13.00	172.24	1324.09	21.59	35.46	7.56	194.09	124.27	1118.82	282.66	280.37
285.00	4.85	13.25	174.75	1343.42	21.92	36.05	7.70	197.71	126.14	1135.70	286.93	284.61
290.00	4.91	13.50	177.26	1362.69	22.24	36.65	7.85	201.34	128.01	1152.53	291.19	288.83
295.00	4.97	13.76	179.76	1381.91	22.57	37.24	7.99	204.96	129.88	1169.32	295.44	293.05
300.00	5.03	14.01	182.25	1401.06	22.90	37.84	8.13	208.58	131.74	1186.07	299.68	297.25
305.00	5.10	14.26	184.73	1420.16	23.22	38.43	8.27	212.21	133.59	1202.77	303.91	301.44
310.00	5.16	14.51	187.21	1439.20	23.55	39.02	8.41	215.83	135.44	1219.43	308.12	305.62
315.00	5.22	14.77	189.68	1458.18	23.87	39.62	8.55	219.45	137.29	1236.05	312.33	309.79

Table 2. Continued.

Hardness mg/L $CaCO_3$	Equation 13 (Cadmium - Chronic) µg/L	Equation 14 (Cadmium - Acute) µg/L	Equation 15 (Chromium III - Chronic) µg/L	Equation 16 (Chromium III - Acute) µg/L	Equation 17 (Copper - Chronic) µg/L	Equation 18 (Copper - Acute) µg/L	Equation 19 (Lead - Chronic) µg/L	Equation 20 (Lead - Acute) µg/L	Equation 21 (Nickel - Chronic) µg/L	Equation 22 (Nickel - Acute) µg/L	Equation 23 (Zinc - Chronic) µg/L	Equation 24 (Zinc - Acute) µg/L
320.00	5.28	15.02	192.14	1477.11	24.20	40.21	8.69	223.07	139.13	1252.63	316.52	313.96
325.00	5.34	15.27	194.60	1495.98	24.52	40.80	8.83	226.69	140.96	1269.16	320.71	318.11
330.00	5.40	15.53	197.05	1514.81	24.84	41.39	8.97	230.31	142.80	1285.66	324.89	322.25
335.00	5.46	15.78	199.49	1533.58	25.16	41.98	9.12	233.92	144.63	1302.12	329.05	326.38
340.00	5.52	16.04	201.92	1552.30	25.48	42.57	9.26	237.54	146.45	1318.55	333.21	330.50
345.00	5.58	16.29	204.35	1570.97	25.80	43.16	9.40	241.16	148.27	1334.93	337.36	334.62
350.00	5.64	16.55	206.77	1589.59	26.12	43.75	9.54	244.77	150.09	1351.28	341.49	338.72
355.00	5.70	16.80	209.19	1608.17	26.44	44.34	9.68	248.38	151.90	1367.60	345.62	342.82
360.00	5.76	17.06	211.60	1626.70	26.76	44.93	9.82	252.00	153.71	1383.87	349.74	346.90
365.00	5.82	17.32	214.00	1645.18	27.08	45.52	9.96	255.61	155.51	1400.12	353.85	350.98
370.00	5.88	17.57	216.40	1663.61	27.39	46.10	10.10	259.22	157.31	1416.33	357.96	355.05
375.00	5.93	17.83	218.79	1682.00	27.71	46.69	10.24	262.83	159.11	1432.50	362.05	359.11
380.00	5.99	18.09	221.18	1700.35	28.02	47.28	10.38	266.43	160.90	1448.64	366.14	363.17
385.00	6.05	18.34	223.56	1718.65	28.34	47.86	10.52	270.04	162.69	1464.75	370.22	367.21
390.00	6.11	18.60	225.94	1736.91	28.65	48.45	10.66	273.64	164.47	1480.83	374.28	371.25
395.00	6.17	18.86	228.31	1755.12	28.97	49.03	10.80	277.25	166.26	1496.88	378.35	375.28
400.00	6.22	19.12	230.67	1773.30	29.28	49.62	10.94	280.85	168.04	1512.89	382.40	379.30

TIER III - WATER QUALITY GUIDELINES

February 1, 2001: Technical Draft for Review and Comment

IMPLEMENTATION POLICIES

General Application

Tier III - Water Quality Guidelines include three general types of guidance. First, *Tier III - Water Quality Guidelines* include a large number of variables derived by the CCME for general application across Canada. Environmental quality guidelines are included for water, lake and river bottom sediments, and residues in fish or other aquatic life tissues for protection of wildlife consumers. Second, *Tier III - Water Quality Guidelines* contain tissue residue guidelines derived by Health Canada to protect human consumers of fish or other aquatic life tissues. Third, *Tier III - Water Quality Guidelines* contain narrative water quality guidelines since numerical guidelines cannot reasonably be developed for every possible chemical, physical, or biological variable.

Tier III - Water Quality Guidelines should be used as follows:

(a) The *Tier III - Numerical Water Quality Guidelines* should be used to assist in the interpretation of ambient water quality data. Ambient water quality data can be compared directly to the water quality guidelines to identify exceedances or long-term trends that may lead to exceedances in the future. If management intervention appears necessary, *Tier III - Water Quality Guidelines* can be advanced to *Tier II - Water Quality Objectives* for application in pollution control activities;

(b) The *Tier III - Numerical Water Quality Guidelines* should be used to assist in identifying if ambient water can sustain specific uses. The water quality guidelines can be used in combination with ambient monitoring data to initially determine whether or not specific bodies of water are suitable for certain proposed uses or activities;

(c) The *Tier III - Narrative Water Quality Guidelines* should be met as minimum conditions at all times and in all places to ensure that all surface and ground water of Manitoba are free of constituents attributable to sewage, industrial, agricultural, and other land-use practices, or other man-induced point or non-point source discharges that may unacceptably impair water quality.

Advancement to Tier II - Water Quality Objectives

Occasionally, *Tier III - Water Quality Guidelines* may need to be advanced to *Tier II - Water Quality Objectives* for direct use in pollution control initiatives. The following general guidance should be followed:

(a) When the minimum toxicological data base requirements of the US EPA (Stephan *et al.* 1985) or subsequent similar methods are met for the protection of aquatic life, modifications may be made to provide a similar level of protection as envisaged for other *Tier II - Water Quality Objectives*.

(b) When the minimum toxicological data base requirements of the US EPA (Stephan *et al.* 1985) or subsequent similar methods are not satisfied to prevent the occurrence of unacceptable adverse effects to aquatic life, *Tier*

III - Water Quality Guidelines should be used as *Tier II - Water Quality Objectives* without modification unless site-specific or regional-specific modifications can be made following CCME guidance (CCME 1999).

(c) For protection of water uses other than aquatic life, *Tier III - Water Quality Guidelines* should be advanced to *Tier II - Water Quality Objectives* using the best available scientific information on exposure-response data, ingestion rates, risk extrapolation techniques, exposure from sources other than surface water, and appropriate safety factors dependent upon the quantity and quality of data or should be used without modification.

Protection of Surface Water Drinking Sources

All surface waters and some shallow, surficial aquifers, including those in remote locations, are susceptible to uncontrolled microbiological contamination. It is therefore assumed that all raw surface water supplies will be disinfected as the minimum level of treatment prior to consumption. The *Tier III - Water Quality Guidelines* contained here apply to finished drinking water, but can be extrapolated to provide protection to raw drinking water sources using the following principles:

(a) It is intended that man-induced water quality alterations not cause an unacceptable increased risk to public health or an unacceptable increased treatment cost to the water user or supplier;

(b) *Tier III - Water Quality Guidelines* should be used, on a site-specific basis, to assist in determining when increased health risks or increased treatment costs may be expected, in conjunction with information concerning:

(i) The chemical, physical or biological quality of the proposed discharge or alteration being considered;

(ii) Ambient or background surface water quality;

(iii) Design of downstream water treatment facilities;

(iv) Other pertinent information.

TIER III - NARRATIVE WATER QUALITY GUIDELINES

Biological Integrity

The biological communities within Manitoba's aquatic ecosystems should not be altered beyond that which would naturally exist such that:

(1) In waters designated as High Quality or Exceptional Value, there should be no change in the species composition, community structure, or community function, and rare or endangered species should be preserved.

(2) In other waters, the species composition should not be altered by more than 5%, community structure should not be altered by more than 20%, there should be no change in community function, important

	recreational, commercial, or ecological species should be protected, and rare or endangered species should be preserved.
	Numerical biological guidelines for specific water bodies may be developed, where possible, and may replace or augment the above narrative guidelines.
Colour, Odour, Taste, Turbidity	Free from materials that produce colour, odour, taste, turbidity, or other conditions in such a degree as to be objectionable or to impair any beneficial use.
Deposits	None that will cause the formation of putrescent or otherwise objectionable sludge deposits.
Floating Materials	Free from floating debris, scum, and other floating materials in sufficient amounts to be unsightly or deleterious.
Flow	Water quantities (flows and lake levels) should not be altered to a degree which will cause exceedances of the water quality standards, objectives, or guidelines such that important uses may be unacceptably impaired. In addition, where practicable, sufficient minimum flows should be maintained to protect aquatic life.
Litter	Free from materials such as garbage, rubbish, trash, cans, bottles, or any unwanted or discarded solid material.
Non-Indigenous Aquatic Species	All reasonable measures should be taken to prevent the accidental introduction of non-native aquatic species into Manitoba or into waters that flow into Manitoba. All intentional introductions of non-native aquatic species into Manitoba or into waters that flow into Manitoba should not be allowed unless it can be demonstrated with scientific rigour that unacceptable environmental impact will not occur.
Nutrients, Nuisance Aquatic Plants, and Toxic Algae	Nitrogen, phosphorus, carbon, and contributing trace elements should be limited to the extent necessary to prevent the nuisance growth and reproduction of aquatic rooted, attached and floating plants, fungi, or bacteria, or to otherwise render the water unsuitable for other beneficial uses. For general guidance, unless it can be demonstrated that total phosphorus is not a limiting factor, considering the morphological, physical, chemical, or other characteristics of the water body, total phosphorus should not exceed 0.025 mg/L in any reservoir, lake, or pond, or in a tributary at the point where it enters such bodies of water. In other streams, total phosphorus should not exceed 0.05 mg/L. It should be noted that maintenance of such concentrations may not guarantee that eutrophication problems will not develop.
Oil and Grease	Free from oil and grease residues which causes a visible film or sheen upon the waters or any discolouration of the surface of adjoining shorelines or causes a sludge or emulsion to be deposited beneath the surface of the water or upon the adjoining shorelines.

Toxic Substances Free from substances in concentrations or in combinations that injure, be toxic to, or produce unacceptable adverse physiological or behavioural responses in humans, aquatic, semi-aquatic, and terrestrial life.

Water Conservation To minimize the withdrawal of water from surface and ground water sources and the subsequent discharge of wastewater, all Manitobans, including municipal, industrial, commercial, institutional, agricultural, and other water-use sectors, are strongly encouraged to develop and implement water efficiency and conservation plans.

TIER III - NUMERICAL WATER QUALITY GUIDELINES

Variable	Surface or Ground Water: Drinking[a] (Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Interim Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Aesthetic Objectives)	Surface Water: Freshwater Aquatic Life[b]	Surface or Ground Water: Irrigation[b]	Surface or Ground Water: Livestock[b]	Surface Water: Recreation[b]	Surface Water: Sediment[b]	Aquatic Life Tissue Residue: Wildlife Consumers[b]	Aquatic Life Tissue Residue: Human Consumers
Acenaphthene [See Polycyclic aromatic hydrocarbons]										
Acenaphthylene [See Polycyclic aromatic hydrocarbons]										
Acridine [See Polycyclic aromatic hydrocarbons]										
Aldicarb	9 µg/L			1 µg/L	54.9 µg/L	11 µg/L				
Aldrin + Dieldrin	0.7 µg/L									
Aluminum				5-100 µg/L	5000 µg/L	5000 µg/L				
Ammonia				*See Tier II - Water Quality Objectives*						
Aniline				2.2 µg/L						
Anthracene [See Polycyclic aromatic hydrocarbons]										
Antimony		6 µg/L								
Antimony-125	100 Bq/L									
Aroclor 1254 [See Polychlorinated biphenyls (PCBs)]										
Arsenic		25 µg/L		*See Tier II - Water Quality Objectives*	100 µg/L	25 µg/L		5900 µg/kg [PEL: 7,000 µg/kg]		3500 µg/kg[c]
Atrazine		5 µg/L		1.8 µg/L	10 µg/L	5 µg/L				
Azinphos-methyl	20 µg/L									
Barium	1000 µg/L									
Bendiocarb	40 µg/L									
Benz*(a)*anthracene [See Polycyclic aromatic hydrocarbons (PAHs)]										
Benzene	5 µg/L			370 µg/L						

Variable	Surface or Ground Water: Drinking[a] (Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Interim Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Aesthetic Objectives)	Surface Water: Freshwater Aquatic Life[b]	Surface or Ground Water: Irrigation[b]	Surface or Ground Water: Livestock[b]	Surface Water: Recreation[b]	Surface Water: Sediment[b]	Aquatic Life Tissue Residue: Wildlife Consumers[b]	Aquatic Life Tissue Residue: Human Consumers
Benz*(a)*anthracene [See Polycyclic aromatic hydrocarbons (PAHs)]										
Beryllium					100 µg/L	100 µg/L				
2,2-Bis(*p*-chlorophenyl)-1,1-dichloroethane [See DDD]										
1,1-Dichloro-2,2-bis(*p*-chlorophenyl)-ethene [See DDE]										
2,2-Bis(*p*-chlorophenyl)-1,1,1-trichloroethane [See DDT]										
Boron		5000 µg/L			500-6000 µg/L	5000 µg/L				
Bromacil				5 µg/L	0.2 µg/L	1100 µg/L				
Bromoform [See Halogenated methanes; Tribromomethane]										
Bromoxynil		5 µg/L		5 µg/L	0.33 µg/L	11 µg/L				
Cadmium	5 µg/L			See *Tier II - Water Quality Objectives*	5.1 µg/L	80 µg/L		600 µg/kg [PEL: 3,500 µg/kg]		
Calcium						1,000,000 µg/L				
Captan				1.3 µg/L		13 µg/L				
Carbaryl	90 µg/L			0.20 µg/L		1100 µg/L				
Carbofuran	90 µg/L			1.8 µg/L		45 µg/L				
Carbon tetrachloride [See Halogenated methanes; Tetrachloromethane]										
Cerium-141	100 Bq/L									
Cerium-144	20 Bq/L									
Cesium-134	7 Bq/L									
Cesium-137	10 Bq/L									
Chloramines [See Reactive Chlorine]										

Variable	Surface or Ground Water: Drinking[a] (Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Interim Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Aesthetic Objectives)	Surface Water: Freshwater Aquatic Life[b]	Surface or Ground Water: Irrigation[b]	Surface or Ground Water: Livestock[b]	Surface Water: Recreation[b]	Surface Water: Sediment[b]	Aquatic Life Tissue Residue: Wildlife Consumers[b]	Aquatic Life Tissue Residue: Human Consumers
Chlordane								4.5 µg/kg [PEL: 8.87 µg/kg]		
Chloride			≤250,000 µg/L		100,000-700,000 µg/L					
Chlorinated benzenes										
Monochlorobenzene	80 µg/L		≤30 µg/L	1.3 µg/L						
1,2-Dichlorobenzene	200 µg/L		≤3 µg/L	0.70 µg/L						
1,3-Dichlorobenzene				150 µg/L						
1,4-Dichlorobenzene	5 µg/L		≤1 µg/L	26 µg/L						
1,2,3-Trichlorobenzene				8.0 µg/L						
1,2,4-Trichlorobenzene				24 µg/L						
1,2,3,4-Tetrachlorobenzene				1.8 µg/L						
Pentachlorobenzene				6.0 µg/L						
Hexachlorobenzene						0.52 µg/L				
Chlorinated ethanes										
1,2-Dichloroethane		5 µg/L		100 µg/L		5 µg/L				
1,1,1-Trichloroethane										
1,1,2,2-Tetrachlorethane										
Chlorinated ethenes										
Monochloroethane (Vinyl Chloride)	2 µg/L									
1,1-Dichloroethene (Dichloroethylene)	14 µg/L									
1,1,2-Trichloroethene [Trichloroethylene, TCE]	50 µg/L			21 µg/L		50 µg/L				
1,1,2,2-Tetrachloroethene [Tetrachloroethylene, PCE]	30 µg/L			111 µg/L						
Chlorinated methanes [See Halogenated methanes]										
Chlorinated phenols										
Monochlorophenol				7 µg/L						
Dichlorophenol				0.2 µg/L						

Variable	Surface or Ground Water: Drinking[a] (Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Interim Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Aesthetic Objectives)	Surface Water: Freshwater Aquatic Life[b]	Surface or Ground Water: Irrigation[b]	Surface or Ground Water: Livestock[b]	Surface Water: Recreation[b]	Surface Water: Sediment[b]	Aquatic Life Tissue Residue: Wildlife Consumers[b]	Aquatic Life Tissue Residue: Human Consumers
2,4-Dichlorophenol	900 µg/L		≤0.3 µg/L							
Trichlorophenol				18 µg/L						
2,4,6-Trichlorophenol	5 µg/L		≤2 µg/L							
Tetrachlorophenol				1 µg/L						
2,3,4,6-Tetrachlorophenol	100 µg/L		≤1 µg/L							
Pentachlorophenol [PCP]	60 µg/L		≤30 µg/L	0.5 µg/L						
Chlorine, Reactive [See Reactive Chlorine]										
Chloroform [See Halogenated methanes; Trichloromethane]										
4-Chloro-2-methyl phenoxy acetic acid [See MCPA]										
Chlorothalonil				0.18 µg/L	5.8 µg/L	170 µg/L				
Chlorpyrifos	90 µg/L			0.0035 µg/L		24 µg/L				
Chromium	50 µg/L							37,300 µg/kg [PEL: 90,000 µg/kg]		
Chromium (III)				See *Tier II - Water Quality Objectives*	4.9 µg/L	50 µg/L				
Chromium (VI)				See *Tier II - Water Quality Objectives*	8 µg/L	50 µg/L				
Chrysene [See Polycyclic aromatic hydrocarbons (PAHs)]										
Cobalt					50 µg/L	1000 µg/L				
Cobalt-60	2 Bq/L									
Coliforms, Fecal					See *Tier II - Water Quality Objectives*		See *Tier II - Water Quality Objectives*			
Coliforms, Total					1000 per 100 mL					
Colour			≤15 TCU							

Variable	Surface or Ground Water: Drinking[a] (Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Interim Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Aesthetic Objectives)	Surface Water: Freshwater Aquatic Life[b]	Surface or Ground Water: Irrigation[b]	Surface or Ground Water: Livestock[b]	Surface Water: Recreation[b]	Surface Water: Sediment[b]	Aquatic Life Tissue Residue: Wildlife Consumers[b]	Aquatic Life Tissue Residue: Human Consumers
Copper			≤1000 µg/L	See *Tier II - Water Quality Objectives*	200-1000 µg/L	500-5000 µg/L		35,700 µg/kg [PEL: 197,000 µg/kg]		
Cyanazine		10 µg/L		2.0	0.5 µg/L	10 µg/L				
Cyanide	200 µg/L			See *Tier II - Water Quality Objectives*						
2,4-D [See 2,4-Dichlorophenoxyacetic acid]										
DDAC [Didecyl dimethyl ammonium chloride]				1.5 µg/L						
DDD [2,2-Bis(*p*-chlorophenyl)-1,1-dichloroethane; Dichloro diphenyl dichloroethane]								3.54 µg/kg [PEL: 8.51 µg/kg]		
DDE [1,1-Dichloro-2,2-bis(*p*-chlorophenyl)-ethene; Diphenyl dichloro ethylene]								1.19 µg/kg [PEL: 4.77 µg/kg]		
DDT [2,2-Bis(*p*-chlorophenyl)-1,1,1-trichloroethan; Dichloro diphenyl trichloroethane]								1.42 µg/kg [PEL: 6.75 µg/kg]		
DDT, Total (sum of DDE, DDD, DDT)									14.0 µg/kg (wet weight)	5000 µg/kg[d]
Deltamethrin				0.0004 µg/L		2.5 µg/L				
Diazinon	20 µg/L									
Dibenz(*a,h*)anthracene [See Polycyclic aromatic hydrocarbons (PAHs)]										
Dibromochloromethane [See Halogenated methanes]										
Di-*n*-butyl phthalate [See Phthalate esters]										
Dicamba	120 µg/L			10 µg/L	0.006 µg/L	122 µg/L				
Dichlorobenzene [See Chlorinated benzenes]										
Dichlorobromomethane [See Halogenated methanes]										

Variable	Surface or Ground Water: Drinking[a] (Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Interim Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Aesthetic Objectives)	Surface Water: Freshwater Aquatic Life[b]	Surface or Ground Water: Irrigation[b]	Surface or Ground Water: Livestock[b]	Surface Water: Recreation[b]	Surface Water: Sediment[b]	Aquatic Life Tissue Residue: Wildlife Consumers[b]	Aquatic Life Tissue Residue: Human Consumers
1,1-Dichloro-2,2-bis(*p*-chlorophenyl)-ethane [See DDE]										
Dichloro diphenyl dichloroethene[2,2-Bis(*p*-chlorophenyl)-1,1-dichloroethane; See DDD]										
Dichloro diphenyl trichloroethane[2,2-Bis(*p*-chlorophenyl)-1,1,1-trichloroethane; See DDT]										
Dichloroethane [See Chlorinated ethanes]										
Dichloroethene [See Chlorinated ethenes]										
Dichloroethylene [See Chlorinated ethenes; 1,1-Dichloroethene]										
Dichloromethane [See Halogenated methanes]										
Dichlorophenol [See Chlorinated phenols]										
2,4-Dichlorophenoxyacetic acid [2,4-D]		100 µg/L								
Diclofop-methyl	9 µg/L			6.1 µg/L	0.18 µg/L	9 µg/L				
Didecyl dimethyl ammonium chloride [See DDAC]										
Dieldrin								2.85 µg/kg [PEL: 6.67 µg/kg]		
Dieldrin + Aldrin [See Aldrin + Dieldrin]										
Diethylene glycol [See Glycols]										
Di(2-ethylhexyl) phthalate [See Phthalate esters]										
Dimethoate		20 µg/L		6.2 µg/L		3 µg/L				

Variable	Surface or Ground Water: Drinking[a] (Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Interim Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Aesthetic Objectives)	Surface Water: Freshwater Aquatic Life[b]	Surface or Ground Water: Irrigation[b]	Surface or Ground Water: Livestock[b]	Surface Water: Recreation[b]	Surface Water: Sediment[b]	Aquatic Life Tissue Residue: Wildlife Consumers[b]	Aquatic Life Tissue Residue: Human Consumers
Di-*n*-butyl phthalate [See Phthalate esters]										
Dinoseb	10 µg/L			0.05 µg/L	16 µg/L	150 µg/L				
Dioxins and Furans (2,3,7,8-TCDD)										0.02 µg/kg[c]
Diphenyl dichloro ethylene [See DDE]										
Diquat	70 µg/L									
Dissolved oxygen [See Oxygen, Dissolved]										
Dissolved solids [See Total dissolved solids]										
Diuron	150 µg/L									
Endosulfan				0.02 µg/L						
Endrin								2.67 µg/kg [PEL: 62.4 µg/kg]		
Ethylbenzene			≤2.4 µg/L	90 µg/L		2.4 µg/L				
Ethylene glycol [See Glycols]										
Fecal coliforms [See Coliforms, fecal]										
Fluoranthene [See Polycyclic aromatic hydrocarbons (PAHs)]										
Fluorene [See Polycyclic aromatic hydrocarbons (PAHs)]										
Fluoride	1500 µg/L				1000 µg/L	1000-2000 µg/L				150,000 µg/kg[c]
Glycols										
Diethylene glycol										
Ethylene glycol				192,000 µg/L						
Propylene glycol				500,000 µg/L						
Glyphosate		280 µg/L		65 µg/L		280 µg/L				
Halogenated methanes										

Variable	Surface or Ground Water: Drinking[a] (Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Interim Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Aesthetic Objectives)	Surface Water: Freshwater Aquatic Life[b]	Surface or Ground Water: Irrigation[b]	Surface or Ground Water: Livestock[b]	Surface Water: Recreation[b]	Surface Water: Sediment[b]	Aquatic Life Tissue Residue: Wildlife Consumers[b]	Aquatic Life Tissue Residue: Human Consumers
Monochloromethane [Methyl chloride]										
Dichloromethane [Methylene chloride]	50 µg/L			98.1 µg/L		50 µg/L				
Trichloromethane [Chloroform]				1.8 µg/L						
Tetrachloromethane [Carbon tetrachloride]	5 µg/L			13.3 µg/L		5 µg/L				
Monobromomethane (Methyl bromide)										
Tribromomethane [Bromoform]										
Tribromomethane (Bromoform)						100 µg/L				
Dichlorobromomethane						100 µg/L				
Dibromochloromethane						100 µg/L				
Trihalomethanes (total)		100 µg/L								
HCBD [See Hexachlorobutadiene]										
Heptachlor (Heptachlor epoxide)								0.60 µg/kg [PEL: 2.74 µg/kg]		
Hexachlorobenzene [See Chlorinated benzenes]										
Hexachlorobutadiene [HCBD]				1.3 µg/L						
Hexachlorocyclohexane [See Lindane]										
Hypochlorous acid [See Reactive chlorine species]										
Iodine-125	10 Bq/L									
Iodine-131	6 Bq/L									
3-Iodo-2-propynyl butyl carbamate [See IPBC]										
IPBC [3-Iodo-2-propynyl butyl carbamate]				1.9 µg/L						
Iron			≤300 µg/L	300 µg/L	5000 µg/L					

Variable	Surface or Ground Water: Drinking[a] (Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Interim Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Aesthetic Objectives)	Surface Water: Freshwater Aquatic Life[b]	Surface or Ground Water: Irrigation[b]	Surface or Ground Water: Livestock[b]	Surface Water: Recreation[b]	Surface Water: Sediment[b]	Aquatic Life Tissue Residue: Wildlife Consumers[b]	Aquatic Life Tissue Residue: Human Consumers
Iron-59	40 Bq/L									
Lead	10 µg/L			*See Tier II - Water Quality Objectives*	200 µg/L	100 µg/L		35,000 µg/kg [PEL: 91,300 µg/kg]		500 µg/kg[c]
Lead-210	0.1 Bq/L									
Lindane [Hexachlorocyclohexane]								0.94 µg/kg [PEL: 1.38 µg/kg]		
Linuron				7.0 µg/L	0.071 µg/L					
Lithium					2500 µg/L					
Malathion	190 µg/L									
Manganese			≤50 µg/L		200 µg/L					
Manganese-54	200 Bq/L									
MCPA [4-Chloro-2-methyl phenoxy acetic acid; 2-Methyl-4chloro phenoxy acetic acid]				2.6 µg/L	0.025 µg/L	25 µg/L				
Mercury	1 µg/L			0.1 µg/L		3 µg/L		170 µg/kg [PEL: 486 µg/kg]		500 µg/kg[d]
Methylmercury									33.0 µg/kg	
Methoxychlor	900 µg/L									
Methyl bromide [See Halogenated methanes, Monobromomethane]										
Methyl chloride [See Halogenated methanes, Monochloromethane]										
Methylene chloride [See Halogenated methanes, Dichloromethane]										
2-Methyl-4-chloro phenoxy acetic acid [See MCPA]										
2-Methylnaphthalene [See Polycyclic aromatic hydrocarbons (PAHs)]										
Metolachlor		50 µg/L		7.8 µg/L	28 µg/L	50 µg/L				

Variable	Surface or Ground Water: Drinking[a] (Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Interim Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Aesthetic Objectives)	Surface Water: Freshwater Aquatic Life[b]	Surface or Ground Water: Irrigation[b]	Surface or Ground Water: Livestock[b]	Surface Water: Recreation[b]	Surface Water: Sediment[b]	Aquatic Life Tissue Residue: Wildlife Consumers[b]	Aquatic Life Tissue Residue: Human Consumers
Metribuzin	80 µg/L			1.0 µg/L	0.5 µg/L	80 µg/L				
Microcystin LR		1.5 µg/L[c]								
Molybdenum				73 µg/L	10-50 µg/L	500 µg/L				
Molybdenum-99	70 Bq/L									
Monobromomethane [See Halogenated methanes]										
Monochloramine [See Reactive chlorine species]										
Monochlorobenzene [See Chlorinated benzenes]										
Monochloroethene [See Halogenated ethenes]										
Monochloromethane [Methyl chloride; See Halogenated methanes]										
Monochlorophenol [See Chlorinated phenols]										
Naphthalene [See Polycyclic aromatic hydrocarbons (PAHs)]										
Nickel				*See Tier II - Water Quality Objectives*	200 µg/L	1000 µg/L				
Niobium-95	200 Bq/L									
Nitrate (as NO_3)	45,000 µg/L									
Nitrate + Nitrite	*See Tier II - Water Quality Objectives*					100,000 µg/L				
Nitrilotriacetic acid [NTA]	400 µg/L									
Nitrite	3,200 µg/L			60 µg/L		10,000 µg/L				
Nitrite + Nitrate [See Nitrate + Nitrite]										
NTA [See Nitrilotriacetic acid]										
Organotins										
Tributyltin				0.008 µg/L		250 µg/L				
Tricyclohexyltin						250 µg/L				

Variable	Surface or Ground Water: Drinking[a] (Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Interim Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Aesthetic Objectives)	Surface Water: Freshwater Aquatic Life[b]	Surface or Ground Water: Irrigation[b]	Surface or Ground Water: Livestock[b]	Surface Water: Recreation[b]	Surface Water: Sediment[b]	Aquatic Life Tissue Residue: Wildlife Consumers[b]	Aquatic Life Tissue Residue: Human Consumers
Triphenyltin				0.022 µg/L		820 µg/L				
Oxygen, Dissolved				See *Tier II - Water Quality Objectives*						
PAHs [See Polycyclic aromatic hydrocarbons]										
Paraquat (as dichloride)		10 µg/L								
Parathion	50 µg/L									
PCBs [See Polychlorinated biphenyls (PCBs)]										
PCE [See Chlorinated ethenes, Tetrachloroethylene; 1,1,2,2-Tetrachloroethene]										
PCP [See Chlorinated phenols, Pentachlorophenol]										
Pentachlorobenzene [See Chlorinated benzenes]										
Pentachlorophenol;[See Chlorinated phenols (PCP)]										
pH			6.5-8.5	6.5-9.0			5.0-9.0			
Phenanthrene [See Polycyclic aromatic hydrocarbons (PAHs)]										
Phenols				4 µg/L		2 µg/L				
Phenoxy herbicides				4 µg/L		100 µg/L				
Phorate	2 µg/L									
Phthalate esters										
Di-*n*-butyl phthalate				19 µg/L						
Di(2-ethylhexyl) phthalate				16 µg/L						
Di-*n*-octyl phthalate										
Picloram		190 µg/L		29 µg/L		190 µg/L				
Polychlorinated biphenyls [PCBs]								34.1 µg/kg [PEL: 277 µg/kg]	0.79 ng TEQ/kg diet	2000 µg/kg[d]

Variable	Surface or Ground Water: Drinking[a] (Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Interim Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Aesthetic Objectives)	Surface Water: Freshwater Aquatic Life[b]	Surface or Ground Water: Irrigation[b]	Surface or Ground Water: Livestock[b]	Surface Water: Recreation[b]	Surface Water: Sediment[b]	Aquatic Life Tissue Residue: Wildlife Consumers[b]	Aquatic Life Tissue Residue: Human Consumers
Aroclor 1254								60 µg/kg [PEL: 340 µg/kg]		
Polycyclic aromatic hydrocarbons [PAHs]										
Acenaphthene				5.8 µg/L				6.71 µg/kg [PEL: 88.9 µg/kg]		
Acenaphthylene								5.87 µg/kg [PEL: 128 µg/kg]		
Acridine				4.4 µg/L						
Anthracene				0.012 µg/L				46.9 µg/kg [PEL: 245 µg/kg]		
Benz*(a)*anthracene				0.018 µg/L				31.7 µg/kg [PEL: 385 µg/kg]		
Benzo*(a)*pyrene	0.01 µg/L			0.015 µg/L				31.9 µg/kg [PEL: 782 µg/kg]		
Chrysene								57.1 µg/kg [PEL: 862 µg/kg]		
Dibenz*(a,h)*anthracene								6.22 µg/kg [PEL: 135 µg/kg]		
Fluoranthene				0.04 µg/L				111 µg/kg [PEL: 2,355 µg/kg]		
Fluorene				3.0 µg/L				21.2 µg/kg [PEL: 144 µg/kg]		
2-Methylnaphthalene								20.2 µg/kg [PEL: 201 µg/kg]		

Variable	Surface or Ground Water: Drinking[a] (Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Interim Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Aesthetic Objectives)	Surface Water: Freshwater Aquatic Life[b]	Surface or Ground Water: Irrigation[b]	Surface or Ground Water: Livestock[b]	Surface Water: Recreation[b]	Surface Water: Sediment[b]	Aquatic Life Tissue Residue: Wildlife Consumers[b]	Aquatic Life Tissue Residue: Human Consumers
Naphthalene				1.1 µg/L				34.6 µg/kg [PEL: 391 µg/kg]		
Phenanthrene				0.4 µg/L				41.9 µg/kg [PEL: 515 µg/kg]		
Pyrene				0.025 µg/L				53.0 µg/kg [PEL: 875 µg/kg]		
Quinoline				3.4 µg/L						
Propylene glycol [See Glycols]										
Pyrene [See Polycyclic aromatic hydrocarbons (PAHs)]										
Quinoline [See Polycyclic aromatic hydrocarbons (PAHs)]										
Radium-224	2 Bq/L									
Radium-226	0.6 Bq/L									
Radium-228	0.5 Bq/L									
Reactive chlorine species				*See Tier II - Water Quality Objectives*						
Chloramines	3000 µg/L									
Ruthenium-103	100 Bq/L									
Ruthenium-106	10 Bq/L									
Selenium	10 µg/L			1.0 µg/L	20-50 µg/L	50 µg/L				
Silver				0.1 µg/L						
Simazine		10 µg/L		10 µg/L	0.5 µg/L	10 µg/L				
Sodium			≤200,000 µg/L							
Streambed substrate [See Total particulate matter]										
Strontium-90	5 Bq/L									
Styrene				72 µg/L						
Sulphate			≤500,000 µg/L			1,000,000 µg/L				

Variable	Surface or Ground Water: Drinking[a] (Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Interim Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Aesthetic Objectives)	Surface Water: Freshwater Aquatic Life[b]	Surface or Ground Water: Irrigation[b]	Surface or Ground Water: Livestock[b]	Surface Water: Recreation[b]	Surface Water: Sediment[b]	Aquatic Life Tissue Residue: Wildlife Consumers[b]	Aquatic Life Tissue Residue: Human Consumers
Sulphide (as H_2S)			≤50 µg/L							
Suspended particulates [See Total particulate matter]										
Suspended sediments [See Total particulate matter]										
TCE [See Chlorinated ethenes, 1,1,2-Trichloroethene]										
Tebuthiuron				1.6 µg/L	0.27 µg/L	130 µg/L				
Temperature			≤15°C	See *Tier II - Water Quality Objectives*						
Terbufos		1 µg/L								
Tetrachlorobenzene [See Chlorinated benzenes]										
Tetrachloroethane [See Chlorinated benzenes]										
Tetrachloroethene [See Chlorinated benzenes]										
Tetrachloroethylene [See Chlorinated ethenes, 1,1,2,2-Tetrachloroethene]										
Tetrachloromethane [See Halogenated methanes]										
Tetrachlorophenol [See Chlorinated phenols]										
Thallium				0.8 µg/L						
Thorium-228	2 Bq/L									
Thorium-230	0.4 Bq/L									
Thorium-232	0.1 Bq/L									
Thorium-234	20 Bq/L									
Toluene			≤24 µg/L	2.0 µg/L		24 µg/L				
Total dissolved solids			≤500,000 µg/L		See *Tier II - Water Quality Objectives*	3,000,000 µg/L				
Total particulate matter										

Variable	Surface or Ground Water: Drinking[a] (Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Interim Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Aesthetic Objectives)	Surface Water: Freshwater Aquatic Life[b]	Surface or Ground Water: Irrigation[b]	Surface or Ground Water: Livestock[b]	Surface Water: Recreation[b]	Surface Water: Sediment[b]	Aquatic Life Tissue Residue: Wildlife Consumers[b]	Aquatic Life Tissue Residue: Human Consumers
Suspended sediments				*See Tier II - Water Quality Objectives*						
Turbidity	1 NTU		≤5 NTU	*See Tier II - Water Quality Objectives*						
Toxaphene								0.1 µg/kg	6.3 µg/kg (wet weight)	1600 µg/kg (not to be consumed)[f] and 200 µg/kg (consumption may be restricted in some cases)[f]
Triallate				0.24 µg/L		230 µg/L				
Tribromomethane [See Halogenated methanes]										
Tributyltin [See Organotins]										
Trichlorobenzene [See Chlorinated benzenes]										
Trichloroethane [See Chlorinated ethanes]										
Trichloroethene [See Chlorinated ethenes]										
Trichloroethylene [See Chlorinated ethenes, 1,1,2-Trichloroethene]										
Trichloromethane [See Halogenated methanes]										
Trichlorophenol [See Chlorinated phenols]										
Tricyclohexyltin [See Organotins]										
Trifluralin		45 µg/L		0.20 µg/L		45 µg/L				

Variable	Surface or Ground Water: Drinking[a] (Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Interim Maximum Acceptable Concentration)	Surface or Ground Water: Drinking[a] (Aesthetic Objectives)	Surface Water: Freshwater Aquatic Life[b]	Surface or Ground Water: Irrigation[b]	Surface or Ground Water: Livestock[b]	Surface Water: Recreation[b]	Surface Water: Sediment[b]	Aquatic Life Tissue Residue: Wildlife Consumers[b]	Aquatic Life Tissue Residue: Human Consumers
Trihalomethanes [See Halogenated methanes]										
Triphenyltin [See Organotins]										
Tritium	7000 Bq/L									
Turbidity [See Total particulate matter]										
Uranium	100 µg/L				10 µg/L	200 µg/L				
Uranium-234	4 Bq/L									
Uranium-235	4 Bq/L									
Uranium-238	4 Bq/L									
Vanadium					100 µg/L	100 µg/L				
Vinyl chloride [See Chlorinated ethenes, Monochloroethene]										
Xylene			≤300 µg/L							
Zinc			≤5000 µg/L	See *Tier II - Water Quality Objectives*	1000-5000 µg/L	50,000 µg/L		123,000 µg/kg [PEL: 315,000 µg/kg]		
Zinc-65	40 Bq/L									
Zirconium-95	100 Bq/L									

Notes:

a Further information on Guidelines for Canadian Drinking Water Quality is available from Health Canada's website at http://www.hc-sc.gc.ca/ehp/ehd/bch/water_quality.htm.

b Canadian Council of Ministers of the Environment (CCME) (1999). Further information on CCME's Canadian Environmental Quality Guidelines is available from their website at http://www.ccme.ca.

c Health Canada's regulations for residues in fish tissue (Division 15, Food and Drugs Act). Further information is available on the Food and Drugs Act from Health Canada's website at http://www.hc-sc.gc.ca/.

d Health Canada's guidelines for residues in fish tissue (pers. comm., Dr. John Salminen, Head, Additives and Contaminants Section, Health Canada).

e The guideline for Microcystin LR has not yet been finalized by the Federal-Provincial Subcommittee on Drinking Water, but is included here at this early stage because of its continued usefulness for assisting to interpret water quality data generated from on-going monitoring programs.

f Ontario Ministry of Environment (1999), derived from Health Canada's Provisional Tolerable Daily Intake of 0.2 µg/kg·bw/day (pers. comm., Dr. John Salminen). Further information on Ontario's consumption guide for sport fish is available from their website at http://www.ene.gov.on.ca/.

RATIONALE FOR PROPOSED REVISIONS, DEFINITIONS, PROGRAM HISTORY, AND REFERENCES

February 1, 2001: Technical Draft for Review and Comment

RATIONALE FOR PROPOSED REVISIONS

Proposed Revision	Rationale
A three-tiered approach is proposed:	A three-tiered approach is proposed to harmonize Manitoba's water quality objectives program with activities of the CCME, while still retaining a number of necessary Manitoba-specific objectives along with associated implementation procedures. The three tiers largely represent differing degrees of implementation flexibility. It is proposed that *Tier I - Water Quality Standards* contain Canada-Wide Standards developed by the CCME. This will principally be the vehicle by which Canada-Wide Standards for water is proposed to be implemented in Manitoba. In addition, it is proposed that *Tier I - Water Quality Standards* contain minimum effluent quality standards arising from the application of best practical treatment technologies. This reflects the simultaneous application of two general water quality management strategies in Manitoba, similar to many other jurisdictions. First, all activities and waste discharges are controlled to the extent that is reasonably practical and economically achievable using a consistent technology-based approach for each development sector. This is consistent with pollution prevention principles that have been historically applied in Manitoba on a routine basis and, more recently, described in the Canadian Council of Ministers of the Environment's (CCME) Canada-Wide Accord on Environmental Harmonization (http://www.ccme.ca). Second, when more stringent environmental controls are required to protect important water uses, a water quality-based approach is then used. Additional environmental limits are derived using the water quality-based approach to ensure that applicable ambient water quality standards, objectives, or guidelines are not exceeded. Although the combined approach of using best practical technology along with ambient quality guidelines has been commonly applied historically in Manitoba, it is proposed that they be explicitly linked in this document as an integral part of water quality management programs. It is proposed that *Tier II - Water Quality Objectives* contain objectives for a short list of materials that are common pollutants in Manitoba. In some cases, *Tier II - Water Quality Objectives* have been site-adapted for Manitoba. *Tier II - Water Quality Objectives* are based on the principles advanced by the United States Environmental Protection Agency (US EPA) that healthy aquatic ecosystems can tolerate some stress and can recover (Stephan 1985, Stephan *et al.* 1985). Based upon this principle, most *Tier II - Water Quality Objectives* were adopted from the US EPA and are intended to

Proposed Revision	Rationale
	provide protection from unacceptable impacts to all but a small percentage of genera (5%). Exceptions are provided for important ecological, recreational, and commercial species, endangered or rare species, and High Quality and Exceptional Value waters that may require additional protection. Therefore, there is good confidence that *Tier II - Water Quality Objectives* will provide a reasonable, cost-effective level of protection without being over-protective or unacceptably under-protective. It is intended that *Tier II - Water Quality Objectives* be used directly to assist in developing discharge limitations. This approach remains unchanged from the previous objectives. It is proposed that *Tier III - Water Quality Guidelines* contain guidelines for numerous materials developed principally by the CCME. Manitoba Conservation actively participates in the CCME process to assist in the development of various environmental management concepts and leadership principles as well as practical tools to assist in the management of man-made stressors to the environment. One of these tools, the CCME environmental quality guidelines (CCME 1999), is becoming recognized world-wide for their value in managing pollutants in the environment. *Tier III - Water Quality Guidelines* are derived by the CCME to ensure that the most sensitive species likely to occur in Canadian waters are protected at all times along with an adequate margin of safety (CCME 1999, Ch. 4, p. 1). Consequently *Tier III - Water Quality Guidelines* generally are more conservative than *Tier II - Water Quality Objectives*. As intended by the CCME, *Tier III - Water Quality Guidelines* will primarily be used in Manitoba to assist in interpreting ambient water quality monitoring data to identify emerging or potential water quality problems. Where required, *Tier III - Water Quality Guidelines* may be elevated to *Tier II - Water Quality Objectives* to assist in developing control strategies for new materials.
Water Quality Standards, Objectives, and Guidelines proposed to now apply to both surface and ground water:	Previously, as indicated by the title, the former Manitoba Surface Water Quality Objectives applied only to surface bodies of water. Although occasionally applied to ground water, such applications were *ad hoc*. This has been remedied in the present proposal by providing explicit water quality protection to ground water.
Re-arrangement of implementation procedures:	Because of the move towards a three-tiered approach with only *Tier II - Water Quality Objectives* intended to be used to assist in deriving end-of-pipe effluent discharge limits, implementation procedures had to be modified slightly and re-organized within the document.
Minimum design stream flows:	A number of changes are proposed to the guidance for minimum design stream flows. For the protection of aquatic life and wildlife, the approach advocated by the US EPA (Stephan *et al.* 1985) is

Proposed Revision	Rationale
	proposed for adoption. That is, it is assumed that healthy aquatic life communities can tolerate some stress and can recover. The US EPA (Stephan *et al.* 1985) advocates that ambient quality objectives not be exceeded more than once each three years, on average. Otherwise, aquatic life communities would be continually in a state of recovery. The US EPA has developed a method to calculate the three-year exceedance frequency (Rossman 1990). The US EPA is still allowing the use of the hydrological-based 7Q10 design flow (US EPA 1991), although the 7Q10 is normally about 10% higher than the design flow calculated by the biological method (US EPA 1994a). Manitoba Conservation is proposing to similarly continue to allow the use of the 7Q10, but would encourage moving to the three-year biological exceedance frequency method. In the past, Manitoba Conservation has allowed 7Q10s to be calculated on a seasonal or monthly basis. While this method will continue to be allowed, the appropriateness of this calculation is presently being reviewed to ensure that it provides the intended level of protection.
Guidance for mixing zones:	The guidance for mixing zones remains generally unchanged with several exceptions. Editorial revisions are proposed in a couple of places to improve the text. While mixing zones in lakes remain defined as not to exceed 10% of the volume available for mixing, an additional qualifier is proposed to limit the size of the mixing zone to 100 m in radius, if this is less than 10% of the volume. This, in part, was derived from US EPA (1994b) in which Region VIII advocate the use of mixing zones in lakes not to exceed 5% of the volume available for mixing and 61 m in radius. Otherwise, at least in large lakes, mixing zones could theoretically occupy a significantly large area or volume. The clause providing guidance on acute lethality within the mixing zone is clarified and strengthened. Similar to the previous guidance, acute lethality is not permitted within the mixing zone. However, in cases where tests show the effluent to be acutely lethal, it is proposed that dischargers be required to demonstrate that mixing is relatively rapid and complete. It is noted that inclusion of this guidance may still not go as far as envisaged by the Federal Fisheries Act where effluents themselves generally should not be acutely toxic to aquatic life.
Reduction of the number of *Tier II - Water Quality*	It is proposed that *Tier II - Water Quality Objectives*, analogous to the former Manitoba Surface Water Quality Objectives, contain

Proposed Revision	Rationale
Objectives (analogous to the former Manitoba Surface Water Quality Objectives):	objectives for only 18 materials that are more commonly regulated in effluent discharges in Manitoba. The remaining approximately 50 materials that are infrequently encountered are proposed to be included as *Tier III - Water Quality Guidelines*. It is appropriate to focus scientific efforts on materials that require common regulation rather than on those that may seldom be encountered. Thus, this approach will allow greater confidence to be developed for the 18 materials included in *Tier II - Water Quality Objectives*. This will ensure that the overall approach is scientifically appropriate for protecting Manitoba's aquatic ecosystems, while still providing means to react in a timely manner to emerging issues.
Adoption of both acute and chronic *Tier II - Water Quality Objectives* is proposed:	This proposed approach was adopted from the US EPA (Stephan *et al.* 1985). Because most *Tier II - Water Quality Objectives* are expressed as averages, limits must be placed on the maximum concentrations that can be tolerated within the averaging period. The longer-term average is intended to protect against unacceptable chronic effects, while the shorter-term average is intended to protect against acute effects.
Adoption of *Tier II - Water Quality Objectives* for metals expressed as dissolved forms rather than total forms is proposed:	It has been generally recognized for some time that the dissolved form of metals is the most toxic; this is the largest fraction available for direct exposure to aquatic life. Many agencies, however, were reluctant to express water quality objectives as the dissolved form since monitoring data were most often generated as total or total recoverable fractions. The US EPA (US EPA 1999b) has now expressed metal criteria as dissolved. This approach is proposed for adoption in Manitoba since it is toxicologically appropriate.
Modification of the definition of Field Crop Irrigation to include the irrigation of parklands and golf courses:	While it was assumed that field crop irrigation also included the application of irrigation water to parklands and golf courses, these uses were not explicitly stated in the previous definition. It is proposed that this now been remedied. This clarification is important since human exposure to high bacteria densities in water can occur during irrigation of parklands and golf courses. Environmental control, therefore, may be required.
A separate irrigation category for the short-term protection of medium to fine textured soils is proposed to no longer be a separate use that requires protection:	Previously, Category C: Field Crop Irrigation provided for the short term protection of medium to fine textured soils. However, prolonged use of irrigation water containing materials at the concentrations listed in the 1988 Manitoba Surface Water Quality Objectives for this category would result in soil damage and loss of fertility. This is no longer considered to be an appropriate management goal and, therefore, is now proposed to be eliminated as a separate use requiring

Proposed Revision	Rationale
	protection.
Secondary Recreation is proposed to no longer be a separate water use that requires protection:	It is proposed that protection of water for secondary recreation activities is no longer necessary. Secondary recreation was defined as "…boating, fishing, and water related activities other than immersion recreation, including navigation and aesthetic enjoyment of scenery. Protection is provided for activities in which water use is incidental, accidental, or sensory, and includes fishing, boating, camping, hunting, and hiking". This designation has been rarely used in the past since secondary recreation is thought to be adequately protected when primary recreational activities are protected. The fecal coliform objective previously used to protect waters used for secondary recreation (1000 organisms/100 mL of sample) is not scientifically defensible nor does it represent an appropriate or useful water quality protection policy.
Tier II - Water Quality Objectives for ammonia:	The previous water quality objective was modified from ammonia criteria advanced by the US EPA in 1984 (US EPA 1985j) The US EPA superceded the 1984 document by publishing new criteria in late 1998 then again in 1999 (US EPA 1999a). The new US EPA criteria reflect new scientific information. This information has been reviewed and has been found to be generally appropriate for application in Manitoba without significant modification. Guidance provided by the US EPA (US EPA 1999a) concerning longer averaging periods and allowable modifications during winter periods is also proposed for adoption. In general, the proposed revised objectives for ammonia are less restrictive than the previous objectives with the exception of conditions during low pHs. Low pH conditions, however, are unusual in most regions of southern Manitoba. Additional modifications may be warranted following completion of studies being conducted by the City of Winnipeg to develop site-specific or regional-specific ammonia water quality objectives for the Red and Assiniboine rivers within and downstream of Winnipeg.
Tier II - Water Quality Objectives for arsenic:	The previous water quality objective was based on water quality criteria published by the US EPA in 1985 (US EPA 1985a). This has been superceded by criteria published by the US EPA in 1999 (US EPA 1999b) and is based upon new scientific information. The new criteria have been reviewed and have been found to be generally appropriate for application in Manitoba without modification. The proposed revised objectives are slightly more restrictive than the previous objectives.
Tier II - Water Quality	The previous water quality objective was based on water quality criteria published by the US EPA in 1985 (US EPA 1985b). This has

Proposed Revision	Rationale
Objectives for cadmium:	been superceded by criteria published by the US EPA in 1999 (US EPA 1999b) and is based upon new scientific information. The new criteria have been reviewed and have been found to be generally appropriate for application in Manitoba without modification. The proposed revised objectives are slightly less restrictive than the previous objectives.
Tier II - Water Quality Objectives for chlorine:	The chronic value remains unchanged but an acute *Tier II - Water Quality Objective* has been proposed for addition (US EPA 1985c).
Tier II - Water Quality Objectives for chromium III:	The previous water quality objective was based on water quality criteria published by the US EPA in 1985 (US EPA 1985d). This has been superceded by criteria published by the US EPA in 1999 (US EPA 1999b) and is based upon new scientific information. The new criteria have been reviewed and have been found to be generally appropriate for application in Manitoba without modification. The proposed revised objectives are more restrictive than the previous objectives.
Tier II - Water Quality Objectives for chromium VI:	The chronic value remains unchanged but an acute *Tier II - Water Quality Objective* has been proposed for addition (US EPA 1985d).
Tier II - Water Quality Objectives for copper:	The previous water quality objective was based on water quality criteria published by the US EPA in 1985 (US EPA 1985e). This has been superceded by criteria published by the US EPA in 1999 (US EPA 1999b) and is based upon new scientific information. The new criteria have been reviewed and have been found to be generally appropriate for application in Manitoba without modification. The proposed revised objectives are slightly more restrictive than the previous objectives.
Tier II - Water Quality Objectives for cyanide:	The chronic value remains unchanged but an acute *Tier II - Water Quality Objective* has been proposed for addition (US EPA 1985f). However, both forms are proposed to be expressed as "Weak Acid Dissociable" rather than "Free Cyanide". While the free cyanide form is most toxic to aquatic life, analytical difficulties prevent accurate estimation of ambient concentrations. The analytical method used to measure "Weak Acid Dissociable" provides a reasonably accurate estimate of the free cyanide fraction.
Tier II - Water Quality Objectives for dissolved oxygen:	Revisions are proposed for the *Tier II - Water Quality Objectives* for dissolved oxygen. It is proposed that the objectives be expressed as concentrations rather than as per cent saturation. The per cent saturation approach has been criticized elsewhere and appears to no longer be used in other jurisdictions (CCME 1999). The per cent saturation approach is too restrictive during cold weather conditions and is slightly under-protective during warm weather conditions. The

Proposed Revision	Rationale
	approach of the US EPA was adopted for dissolved oxygen (US EPA 1986). This approach is similar to that recommended by the CCME.
Tier II - Water Quality Objectives for fecal coliform bacteria:	The *Tier II - Water Quality Objectives* for fecal coliform bacteria for protection of primary recreation and irrigation water uses remains unchanged from the previous objectives. An objective is proposed to be added to protect ground water aquifers used as sources of drinking water from contamination by fecal material. Fecal coliform densities should be zero in ground water aquifers used as sources of drinking water. This is because most ground water aquifers are reasonably well protected from contamination by fecal material. Because of this high level of natural protection, drinking water is often obtained from ground water with little or no treatment unlike drinking water obtained from surface sources.
Tier II - Water Quality Objectives for lead:	The previous water quality objective was based on water quality criteria published by the US EPA in 1985 (US EPA 1985g). This has been superceded by criteria published by the US EPA in 1999 (US EPA 1999b) and is based upon new scientific information. The new criteria have been reviewed and have been found to be generally appropriate for application in Manitoba without modification. The proposed revised objectives are slightly more restrictive than the previous objectives.
Tier II - Water Quality Objectives for nickel:	The previous water quality objective was based on water quality criteria published by the US EPA in 1985 (US EPA 1985h). This has been superceded by criteria published by the US EPA in 1999 (US EPA 1999b) and is based upon new scientific information. The new criteria have been reviewed and have been found to be generally appropriate for application in Manitoba without modification. The proposed revised objectives are more restrictive than the previous objectives.
Tier II - Water Quality Objectives for nitrate - nitrite:	The previous Manitoba Surface Water Quality Objectives contained an objective for nitrate-nitrite in surface water used as sources of drinking water. It is proposed that this now be changed to apply only to ground water aquifers used as sources of drinking water. Nitrate-nitrite concentrations rarely approach the objective of 10 mg/L in surface water systems but often approach or exceed this concentration in ground water. Management intervention may then be required for ground water. A *Tier III - Numerical Water Quality Guideline* is still retained to address isolated drinking water concerns that may arise regarding nitrate-nitrite concentrations in surface waters.
Tier II - Water Quality Objectives for sodium	Unchanged from the previous version.

Proposed Revision	Rationale
adsorption ratio (SAR):	
Tier II - Water Quality Objectives for temperature:	Unchanged from the previous version.
Tier II - Water Quality Objectives for total dissolved solids and conductivity:	Unchanged from the previous version.
Tier II - Water Quality Objectives for total suspended sediment and turbidity:	The previous water quality objective for total suspended solids was expressed as a concentration of 25 mg/L and was intended to not be exceeded at any time. However, most streams, at least in the southern region of Manitoba, have natural concentrations of suspended sediments that range over 200 mg/L, especially during spring run-off. The existing objective, therefore, was very difficult to apply. Other jurisdictions have addressed this issue by expressing ambient quality objectives for suspended sediments as a relative change from natural background. In this regard, it is proposed that the approach developed by British Columbia in 1998 be adopted (B.C. Environment 1998). Natural background is defined as historical, pre-development concentrations, the upstream concentration existing at any given time, or when necessary, the concentration in an adjacent, undisturbed water body with similar hydrological and geological properties.
Tier II - Water Quality Objectives for zinc:	The previous water quality objective was based on water quality criteria published by the US EPA in 1985 (US EPA 1985i). This has been superceded by criteria published by the US EPA in 1999 (US EPA 1999b) and is based upon new scientific information. The new criteria have been reviewed and have been found to be generally appropriate for application in Manitoba without modification. The proposed revised objectives are more restrictive than the previous objectives when hardness is less than 33.7 mg/L and are less restrictive when hardness is greater than 33.7 mg/L.
Tier III - Narrative Water Quality Guidelines proposed for biological integrity:	Narrative biological guidelines are proposed to ensure the protection of ecosystem structure and function. These will augment the comprehensive chemical-specific guidelines. Criteria defining biological integrity have successfully been included in water quality standards programs in many US jurisdictions for a number of years (*e.g.*, US EPA 1990). In anticipation of the proposed inclusion of biological guidelines, Manitoba Conservation incorporated sampling programs for aquatic macroinvertebrates into the routine water quality monitoring program in 1995.
Tier III - Narrative Water Quality Guidelines for plant	Narrative guidelines are still retained for nutrients such as nitrogen and phosphorus, although it is generally recognized that the narrative guidelines for phosphorus likely do not apply to many streams in the

Proposed Revision	Rationale
nutrients:	Canadian prairie region since other factors such as turbidity, stream velocity, nitrogen, and other conditions most often limit algal growth. As well, relatively high levels of phosphorus in excess of the narrative guidelines may arise naturally from the rich prairie soils. To remedy the identified concerns with the narrative objectives for nutrients, Manitoba Conservation, similar to other jurisdictions, is developing a strategy to better manage plant nutrients in our aquatic ecosystems. It is anticipated that this strategy will lead to the development of more appropriate site-specific or regional-specific water quality objectives or guidelines for nutrients. Once developed, these will be incorporated into future editions of this document. Some useful information that may assist in the development of appropriate numerical water quality objectives for nutrients may arise from studies presently being conducted by the City of Brandon on the Assiniboine River.
Tier III - Narrative Water Quality Guidelines proposed for maintenance of minimum in-stream flows:	It is proposed that a narrative guideline be added to ensure that sufficient minimum in-stream water flows are maintained, where practicable, to ensure the protection of aquatic life communities. Minimum in-stream flows are presently being developed both for a number of major streams within Manitoba and along the transboundary regions.
Tier III - Narrative Water Quality Guidelines proposed for water conservation measures:	It is proposed that narrative guidelines be added to guide the development of water conservation measures. One major facet of environmental protection programs includes the minimization of consumptive uses of high quality water. This narrative guideline is intended to encourage the development of water conservation measures and ultimately, to result in the need to discharge less wastewater.
Tier III - Narrative Water Quality Guidelines proposed for non-indigenous aquatic species:	It is proposed that narrative guidelines be added to guide the intentional introduction of non-native aquatic species to Manitoba waters and to prevent the accidental introduction of other, potentially harmful, non-native aquatic species. Harmful, exotic aquatic species have caused major impacts to aquatic ecosystems in other jurisdictions and have the potential to cause similar damage in Manitoba. This narrative guideline reflects the intent to continue to take all reasonable measures to prevent the accidental introduction of foreign species. As well, guidance is offered in those cases where intentional introductions of commercially- or recreationally-viable non-native species are being considered.
Tier III - Numerical Water Quality Guidelines proposed	It is proposed that sediment and tissue residue guidelines be included for many persistent materials that may accumulate in lake or river

Proposed Revision	Rationale
for adopted from various Canadian sources for the protection of water, bottom sediments, fish tissue consumed by wildlife, and fish tissue consumed by humans:	bottom sediments and fish tissue. Residue guidelines in bottom sediments and in fish tissue were developed by the CCME principally to protect aquatic life and wildlife consumers of aquatic life (CCME 1999). Additional guidelines developed by Health Canada (*e.g.*, Division 15, Food and Drugs Act) and by other Canadian jurisdictions (Ontario Ministry of Environment 1999) are also proposed for adoption that are intended to protect human consumers of aquatic life.

DEFINITIONS

Water Uses — Water uses in Manitoba requiring protection include the following:

- **Drinking Water** — Waters which are or may be used for human consumption, culinary, food processing purposes, and other household purposes.

- **Cool Water Aquatic Life and Wildlife** — Fish species and additional flora and fauna which are indigenous to a cool water habitat (*e.g.*, mooneye, goldeye, pike, perch, walleye, sauger) including those forms of wildlife that rely upon surface waters for habitat and for food supplies. Additional flora and fauna include other aquatic organisms such as bacteria, fungi, algae, aquatic insects, other aquatic invertebrates, reptiles, amphibians, and fish.

- **Cold Water Aquatic Life and Wildlife** — Fish species in the family Salmonidae (*e.g.*, char, trout, whitefish, grayling) and additional flora and fauna which are indigenous to a cold water habitat including those forms of wildlife that rely upon surface waters for habitat and for food supplies. Additional flora and fauna include other aquatic organisms such as bacteria, fungi, algae, aquatic insects, other aquatic invertebrates, reptiles, amphibians, and fish.

- **Industrial and Cooling Water Supplies** — Waters which are or may be used as a source of supply for industrial processes or cooling water, or any other industrial, commercial purposes, or private purpose and for which quality control is or may be necessary.

- **Greenhouse Irrigation** — Waters which are or may be used for intensive horticultural crop production, where irrigation is used as the only source of water. Long-term protection is afforded (1) fine, medium, and coarse textured soils from the accumulation of substances that may be harmful or cause a reduction in fertility; (2) sensitive, semi-tolerant, and tolerant species of plants; and (3) humans from the harmful effects caused by the accumulation of substances on marketable produce that may not be processed prior to consumption.

- **Field Crop Irrigation** — Waters which are or may be used for field crop production, golf courses, parklands, and other areas where irrigation water is used to supplement natural precipitation. Long-term protection is afforded (1) fine, medium, and coarse textured soils from the accumulation of substances that may be harmful or cause a reduction in fertility; (2) sensitive, semi-tolerant and tolerant species of plants; and (3) humans from harmful effects caused by the accumulation of substances on marketable produce that may not be processed prior to consumption.

- **Livestock Watering** — Waters which are or may be used by livestock and poultry. Protection is afforded all classes and ages of livestock and poultry from unacceptable effects following water consumption. Disinfection may be required for waters heavily contaminated with wastes of fecal origin in order to provide a suitable supply for ingestion by monogastric animals (poultry, swine, horses).

• Primary Recreation	Waters which are or may be used for primary recreational uses where the human body may come in direct contact with the water, to the point that water may be ingested accidentally or water may contact certain sensitive organs such as the eyes, ears, and nose. Examples could include wading and dabbling, swimming, diving, water skiing, surfing, and contact with water directly associated with shoreline activities.
4-Day, 3-Year Biological-Based Minimum Design Flow	The 4-day, 3-year biological-based design flow is calculated by an iterative convergence procedure in five steps (Rossman 1990) and estimates the flow which occurs, on average, once each 3 years from 4-day running harmonic averages during the period of record. Biologically-based minimum design flows of other duration and frequency (*e.g.*, 1-day, 3-year; 30-day, 3-year; or others) can be calculated in the same manner.
7Q10 Hydrological-Based Minimum Design Flow	The 7Q10 hydrological-based design flow is the minimum 7-day average flow which occurs with a return frequency of once in each 10 years. It is an extreme value design flow estimated in three steps by calculating 7-day running arithmetic averages for the period of record, fitting the annual minima to a log Pearson III probability distribution, then selecting the value from the distribution with a probability of not being exceeded of 1/10 years or 0.10. Other hydrological extreme value design flows such as 1Q10, 30Q10, or others can be calculated in the same manner. The method is described by Rossman (1990).
96 hour LC_{50}	The concentration of a material that results in the death of 50% of the test organisms over a period of 96 hours.
Acute Lethality	A toxic effect resulting in death produced in an organism by a substance or mixture of substances within a short exposure period (usually 96 hours or less).

Canada-Wide Standards

The following has been excerpted from the CCME website at http://www.ccme.ca: "Canada-Wide Standards (CWSs) can include qualitative or quantitative standards, guidelines, objectives, and criteria for protecting the environment and reducing the risk to human health. CWSs will include a numeric limit (*e.g.*, ambient, discharge, or product standard), a commitment and timetable for attainment, a list of preliminary actions to attain the standard, and a framework for reporting to the public.

CWSs are intended to be achievable targets and will be based on sound science. CWSs will consider other factors such as social aspects (*e.g.*, effects on jobs), economic impacts (*e.g.*, costs associated with solving the problem), and technical feasibility (for example, availability of technology). Public input will be a key feature in the development of CWSs. Governments are responsible for implementing the CWS and are accountable to the public for doing so. CWSs do not themselves have any legal force. In implementing the standards, governments may choose to use their existing legal authorities, or create new ones where necessary.

Several features of the emerging CWS process differ from those used for traditional guideline development. First, socio-economic and technical factors must be duly considered in the development of CWSs. CCME guidelines for the ambient environment focus principally on prevention of adverse environmental effects. Socio-economic factors are not generally accommodated in guidelines, although such factors can be used to develop site-specific or regional-specific objectives from guidelines. Second, greater public participation is planned for the development of CWSs. It is expected that public participation in some form will occur at various stages in the process. Third, through preparation of implementation workplans, governments will demonstrate a commitment to attain the CWS. In the case of guidelines, implementation has been very much at the discretion of the individual jurisdiction. Jurisdictional powers are not altered under the CWS exercise; however, jurisdictions commit to stating their course of action. Finally, in implementing a CWS, jurisdictions agree to report publicly on the results achieved."

Mixing Zones

Mixing zones are areas adjacent to a discharge or to an activity that may affect water quality where, in particular, not all *Tier II - Water Quality Objectives* are met but acutely toxic conditions are prevented. Mixing zones are usually comprised of a zone of initial dilution and a secondary zone of mixing. Mixing zones are allowed for practical reasons since, for most pollutants, it would be unreasonable to require the objectives to be met at the end of the discharge pipe.

Sodium Adsorption Ratio (SAR)

$$= \frac{0.044 \times [\text{Sodium}]}{\sqrt{(0.025 \times [\text{Calcium}]) + (0.041 \times [\text{Magnesium}])}}$$

where sodium, calcium, and magnesium are concentrations expressed in mg/L.

Units

µg/L micrograms per litre (approximately equivalent to parts per billion).

Bq/L Becquerels per litre.

pBq/L picoBecquerels per litre

mg/kg milligrams per kilogram (equivalent to parts per million).

µg/kg micrograms per kilogram (equivalent to parts per billion).

mg/L milligrams per litre (approximately equivalent to parts per million).

ng/kg nanograms per kilogram (equivalent to parts per trillion).

NTU Nephelometric Turbidity Units

TCU True Colour Units.

TEQ Toxic Equivalents (to relate toxicity to standard units derived for dioxin).

PEL Probable Effects Level.

PROGRAM HISTORY

1976	Manitoba Environment developed a proposal detailing a system of surface water quality objectives and watershed classifications for the Province of Manitoba.
1979	The original 1976 proposal was modified slightly following widespread public review (Clean Environment Commission 1979).
1980	The Souris River watershed was classified according to water uses and water quality objectives were assigned (Clean Environment Commission 1980).
1981	The Red River watershed was classified according to water uses and water quality objectives were assigned (Clean Environment Commission 1981).
1982	The Grass-Burntwood watersheds were classified according to water uses and water quality objectives were assigned (Clean Environment Commission 1982).
1983	A number of major technical revisions were proposed for the program in 1983 (Williamson 1983a, 1983b).
1984	The 1983 proposed revisions were the subject of widespread scientific, technical, and public review. The public review culminated with a two-day public hearing, held in Winnipeg during November 1984.
1988	Several additional revisions were made to the 1983 proposals subsequent to the 1984 public hearings and the revised document was released on July 31, 1988 (Williamson 1988a). Accompanying the revised Manitoba Surface Water Quality Objectives report was a rationale document describing the reasons for the latter series of revisions, including an explanation of the most controversial parts of the program, and containing the Clean Environment Commission's report on the findings of their public hearings held in 1984 (Williamson 1988b).
1988	The Environment Act, proclaimed in Manitoba in March 1988, provided legislative support for the Department's role in the development and implementation of water quality standards, objectives, and guidelines.
1990	Government-wide support for the development and implementation of water quality objectives in Manitoba was provided in the development of provincial sustainable development water strategies (Sustainable Development Coordination Unit 1990).

1990 - 1991	Clean Environment Commission public hearings were held to consider setting water quality objectives for the Red and Assiniboine rivers and their tributaries within and downstream of the City of Winnipeg. The Clean Environment Commission presented their report to the Honourable J. Glen Cummings, Manitoba Environment, in June 1992 (Clean Environment Commission 1992).
2000 - 2001	Major revisions proposed to Manitoba Conservation's water quality objectives program.

REFERENCES

B.C. Environment. 1998. Ambient water quality guidelines (criteria) for turbidity, suspended and benthic sediments - Overview. Water Management Branch. British Columbia Ministry of Environment, Lands, and Parks.

CCME. 1999. Canadan Environmental Quality Guidelines. Canadian Council of Ministers of the Environment. Vinnipeg MB.

CCREM. 1987. Canadan Water Quality Guidelines. Canadian Council of Ministers of Resource and Environment Mnisters. Winnipeg MB.

Clean Environment Commission. 1979. Report on a proposal concerning surface water quality objectives and stream classification for the Province of Manitoba. The Clean Environment Commission, Winnipeg MB.

Clean Environment Commission. 1980. Report on a proposal for the classification of Manitoba's surface water: Souris River Principal Watershed Division. The Clean Environment Commission, Winnipeg MB.

Clean Environment Commission. 1981. Report on a proposal for the classification of Manitoba's surface water: Red River Principal Watershed Division. The Clean Environment Commission, Winnipeg MB.

Clean Environment Commission. 1982. Report on a proposal for the classification of Manitoba's surface water: Grass-Burntwood Rivers Principal Watershed Division. The Clean Environment Commission, Winnipeg MB.

Clean Environment Commission. 1992. Report on public hearings: Application of water quality objectives for the watershed classification of the Red and Assiniboine rivers and tributaries within and downstream of the City of Winnipeg. The Clean Environment Commission, Steinbach MB.

Health and Welfare Canada. 1992. Guidelines for Canadian recreational water. Prepared by the Federal-Provincial Working Group on Recreational Water Quality for the Federal-Provincial Advisory Committee on Environmental and Occupational Health.

Health and Welfare Canada. 1996. Guidelines for Canadian Drinking Water Quality. Sixth Edition. Prepared by the Federal-Provincial Subcommittee on Drinking Water of the Federal-Provincial Advisory Committee on Environmental and Occupational Health.

MacDonald, D.D. 1997. Methods for deriving site-specific water quality objectives in British Columbia and Yukon. MacDonald Environmental Sciences Ltd. for Water Management Branch, B.C. Ministry of Environment, Lands, and Parks.

National Academy of Sciences/National Academy of Engineering. 1973. Water Quality Criteria, 1972. EPA.R3.73.033.

Ontario Ministry of Environment. 1999. Guide to Eating Ontario Sport Fish, 1999 - 2000.

Rossman, L.A. 1990. DFLOW User's Manual. United States Environmental Protection Agency. Document EPA 600/8-90/051.

Stephan, C.E. 1985. Are the "Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Life and Its Uses" based on sound judgments? Aquatic Toxicology and

Hazard Assessment: Seventh Symposium, ASTM STP 854, pp. 515-526. Eds. Cardwell, R.D., R. Purdy, and R.C. Bahner. American Society for Testing and Materials, Philadelphia.

Stephan, C.E., D.I. Mount, D.J. Hansen, J.H. Gentile, G.A. Chapman and W.A. Brungs. 1985. Guidelines for deriving numerical national water quality criteria for the protection of aquatic organisms and their uses. United States Environmental Protection Agency. Tech. Rpt. PB85-227049.

Sustainable Development Coordination Unit. 1990. Applying Manitoba's Water Policies. Manitoba Government.

U.S. EPA. 1976. Quality Criteria for Water. United States Environmental Protection Agency.

U.S. EPA. 1985a. Ambient water quality criteria for arsenic - 1984. Environmental Protection Agency. Document EPA 440/5-84-033.

U.S. EPA. 1985b. Ambient water quality criteria for cadmium - 1984. United States Environmental Protection Agency. Document EPA 440/5-84-032.

U.S. EPA. 1985c. Ambient water quality criteria for chlorine - 1984. United States Environmental Protection Agency. Document EPA 440/5-84-030.

U.S. EPA. 1985d. Ambient water quality criteria for chromium - 1984. United States Environmental Protection Agency. Document EPA 440/5-84-029.

U.S. EPA. 1985e. Ambient water quality criteria for copper - 1984. United States Environmental Protection Agency. Document EPA 440/5-84-031.

U.S. EPA. 1985f. Ambient water quality criteria for cyanide - 1984. United States Environmental Protection Agency. Document EPA 440/5-84-028.

U.S. EPA. 1985g. Ambient water quality criteria for lead - 1984. United States Environmental Protection Agency. Document EPA 440/5-84-027.

U.S. EPA. 1985h. Ambient water quality criteria for nickel - 1984. United States Environmental Protection Agency. Document EPA 440/5-80-064.

U.S. EPA. 1985i. Ambient water quality criteria for zinc - 1984. United States Environmental Protection Agency. Document EPA 440/5-80-079.

U.S. EPA. 1985j. Ambient water quality criteria for ammonia - 1984. United States Environmental Protection Agency. Document EPA 440/5-85-001.

U.S. EPA. 1986. Ambient water quality criteria for dissolved oxygen. United States Environmental Protection Agency. Document EPA 440/5-86-003.

U.S. EPA. 1990. Biological Criteria. National Program Guidance for Surface Waters. United States Environmental Protection Agency. Document EPA-440/5-90-004.

U.S. EPA. 1991. Technical support document for water quality-based toxics control. United States Environmental Protection Agency. Document EPA-505-2-90-001.

U.S. EPA. 1994a. Water Quality Standards Handbook, Second Edition. United States Environmental Protection Agency. Document EPA-823-B-94-005a.

U.S. EPA. 1994b. Mixing Zones and Dilution Policy - EPA Region VIII. Region VIII, Water Management Division. United States Environmental Protection Agency.

U.S. EPA. 1995. Great Lakes Water Quality Initiative criteria documents for the protection of aquatic life in ambient water. United States Environmental Protection Agency. Document EPA-820-B-95-004.

U.S. EPA. 1999a. Update of Ambient Water Quality Criteria for Ammonia. United States Environmental Protection Agency. Document EPA 822-R-99-014.

U.S. EPA. 1999b. National recommended water quality criteria - correction. United States Environmental Protection Agency. Document EPA 822-Z-99-001.

Williamson, D.A. 1983a. Surface water quality management proposal. Volume 1: Surface water quality objectives. Water Standards and Studies Report #83-2. Manitoba Department of Environment and Workplace Safety and Health.

Williamson, D.A. 1983b. Surface water quality management proposal. Volume 2: Watershed classifications. Water Standards and Studies Report #83-3. Manitoba Department of Environment and Workplace Safety and Health.

Williamson, D.A. 1988a. Manitoba surface water quality objectives. Water Standards and Studies Section, Manitoba Department of Environment.

Williamson, D.A. 1988b. Rationale document supporting revisions to Manitoba surface water quality objectives. Water Standards and Studies Section, Manitoba Department of Environment.